AIRLINE HUBS: CHANGES IN URBAN EMPLOYMENT STRUCTURE AND NETWORK CONNECTIVITY

By

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The deregulation of the domestic airline industry in the U.S. brought about many changes in air transportation. Carriers have come and gone, fares have fluctuated and enplanement figures have risen tremendously. Fundamental changes have also occurred in the geographic structure of the air transport network. In particular, the hub-and-spoke system has been adopted by major carriers and has led to increases in flow efficiency and connectivity. One or more cities are chosen by the airline as a regional collection point for passengers. Passengers from many different origins are funneled into the hub city to connect with flights to their final destinations. Hub cities, therefore, are characterized by having many nonstop destinations available from their airports.

Living and working in hub cities can have tremendous benefits for the time-sensitive traveler. Professional employees such as research scientists and engineers, managers and salesmen fall into this category. Face-to-face communication is an important part of their job as they are often required to travel quickly to a client, other facilities of the firm or yet another city. Recent industrial location literature and surveys of corporations imply that the high quality air transportation that hub cities offer is extremely desirable when locating or relocating these nonroutine employees of the firm. The purpose of this study was to link the changes in connectivity that occur as a city is chosen to be an airline hub to changes in professional employment growth.

The analysis of this study, however, fails to show a significant relationship between changes in air service connectivity and professional employment growth in the 60 MSAs in the study set over the period from 1978 through 1988.

CHAPTER 1
INTRODUCTION

The deregulation of the domestic airline industry has brought about many changes in air travel in the United States. Both new and older, established carriers have disappeared in bankruptcy courts or through mergers with other carriers. Fares dropped tremendously at first, but have been on the rise since the end of the 1980s, and passenger enplanements have skyrocketed.

Another significant change has been in the geographic structure of the air travel network itself. Fewer nonstop flights are available to some cities than before, as service is now fed into hub cities of specific carriers instead of most or all larger cities within a region. This study will examine changes in the professional employment structure of those hub cities as their connectivity levels rise.

Hub-and-Spoke Structure

Hub cities act as a collection point of air passengers in a region and thus have a tremendous amount of flow in and out of them. Passengers are flown into the city from many

different origins to connect with flights to their final destinations. Hub cities, therefore, have a multitude of nonstop alternatives available to local residents.

Connectivity Change and the Location of Economic Activities

It can be posited that the restructuring of air networks can greatly influence the location of economic activities. Because of the large number of nonstop flights and destinations from hub airports, certain corporate activities should find it advantageous to be located in a hub city.

Who is the corporate traveler? What types of positions within the firm would require frequent air travel? Typically such employees are those for whom a lot of face-to-face, nonroutine communication both within and outside of the firm is vital. Even though communication technology has made phenomenal advancements in recent years, situations occur for which there is no viable alternative or substitute for an on-site visit. Firms desire close contact with their clients and markets to respond quickly to their changing needs. Managers, sales staff, scientists, engineers and other administrative employees are often required to travel quickly to other parts of the company, to clients, or to other locations. In order to minimize travel time, it is preferable to fly nonstop to one's final destination rather than to fly two or more flight segments with layovers in between. The savings in total

travel time can be very significant to a profit-oriented organization as well as the general public.

Objectives

How do hub cities measure up? Do they indeed have a higher concentration of employees from management and research and development labs? More importantly, has the change to a hub-and-spoke network yet enhanced the attractiveness of newly designated hub cities? Investigation of these issues is the focus of this study.

Data will be collected and analyzed from various publications of the Official Airline Guide, Inc., the U.S. Census Bureau and the Federal Aviation Administration for each year from 1978 through 1988 to examine the degree to which changes in connectivity that occur when an airline chooses a particular city as a transfer hub are related to changes in employment growth of the above-mentioned type.

Structure of Presentation

Chapter 2 presents a review of the pertinent industrial location literature, while Chapter 3 discusses the domestic air transportation industry before and after deregulation. These two chapters will build a framework within which to place this dissertation in the broader perspective of

industrial location and air transportation research. In Chapter 4, variations in hub service quality and connectivity are discussed and a hub classification scheme (based on connectivity) is derived using binary matrix analysis. The main analysis (methodology and results) of this dissertation is presented in Chapter 5. Chapter 6 is a summary of the study and directions of future research.

CHAPTER 2
INDUSTRIAL LOCATION DECISIONS

Introduction

Different activities of the firm have different locational requirements. Nonroutine activities, such as management and research and development, are less influenced by wage rates and site location costs than routine activities, such as manufacturing. This chapter will look at the location of organizations in the context of spatial division of labor, and identify the specific locational needs of the various activities of the firm. It also includes a discussion of professional workers and the role they play in business location decisions. Therefore, this chapter is an important component of the study since it will help identify places where professional workers are likely to be concentrated.

Theory of Location of Organizations

Traditionally, industrial location theory has been based on profit maximization through the minimization of costs (Alexander, Gibson, 1979; Boyce, 1978; Chapman, Walker, 1987; De Souza, 1990; De Souza, Foust, 1979; Dicken, Lloyd, 1990; Hoover, 1948; Wheeler, Muller, 1986). Transportation costs

and the locations of raw materials and markets were major concerns. One of the main flaws in this approach, however, is the assumption that labor quality, supply and cost are the same at all locations (Moriarty, 1980; Watts, 1987). Elaborate models to determine minimum-cost sites focused, consequently, solely on transportation costs as spatially variable (Dicken, Lloyd, 1990).

A broader view of industrial location theory, on the other hand, holds that labor is the key to determining firm location since, in reality, labor has a high degree of spatial differentiation in terms of both supply and level of skill and, therefore, cost (Storper, Walker, 1984). This differentiation of labor also occurs according to both industry (industries differ in their mix of labor) and function within the firm, such as marketing, research and development or routine manufacturing. Thus, the geographic pattern of industry represents the spatial division of labor as particular industries, as well as particular activities of the firm, correspond to the geographic location of labor (Blair, Premus, 1987; Czamanski, 1981; Massey, 1984; Storper, Walker, 1983).

Spatial division of labor within the firm has become quite commonplace and has been the subject of much academic work (Schoenberger, 1986, 1987; Watts, 1987). Technological improvements in communication and automation have increased the spatial separability of parts of the production process

and of organizational functions (Storper, Walker, 1983). The different parts of the organization can search for locations that will more greatly benefit their specific tasks or roles within the firm, without the necessity of being physically or locationally tied to other functions of the organization that might have entirely different locational requirements. As the spatial variations in cost, quality and availability of nonlabor inputs have largely diminished, the issue of labor has risen greatly in importance (Moriarty, 1980; Storper, Walker, 1984).

Spatial Division of Labor

Because a supply of unskilled labor for standardized, routine production is virtually ubiquitous, labor-intensive manufacturing and assembly operations can locate almost anywhere (Blair, Premus, 1987; Clark, 1981; Czamanski, 1981; Massey, 1984; Schmenner, 1982). When the manufacturing procedure does become standardized or routine, firms will establish branch plants--often in nonurban areas with depressed local labor markets to reduce labor competition (Erickson, Leinbach, 1979). Labor-intensive operations primarily seek to reduce labor costs (to obtain higher profits for the firm) and generally locate or relocate in low-wage areas anywhere in the world. Such areas are typically located outside of the traditional innovative centers of industry

since production need not be linked to innovative research and development, which relies on highly skilled labor. Production shifts to these peripheral regions from high-cost core regions because the competition for labor in large urban areas, and therefore the price paid for labor, has increased to the point where profit margins are unacceptably low or nonexistent (Barkley, 1988; Markusen, 1985). Thus, routine operations in both manufacturing and services have largely decentralized to peripheral areas within developed countries and to developing countries (Clark, 1981; Schoenberger, 1986, 1987).

These industrial location shifts can be explained by Vernon's product life cycle theory (1966). Industries, firms and products move down the urban hierarchy as they go through different stages (each with distinct locational requirements, labor needs, growth rates and profitability) in their life cycle (Barkley, 1988). Mobility of the various functions of the firm is often a necessity for firm survival, influenced by the potential for profit in each stage.

The profit cycle model complements the insights from the project life cycle model. Markusen (1985) describes the long-term profit cycle as having five characteristic stages. In stage one (zero profit), output is very low (often done in test runs) while a new product or new design is being initiated. Costs per unit are high since the primary workforce involved is composed of many nonroutine workers, such as scientists, engineers and other technicians, who are

experimenting with the test runs. Production is usually concentrated at or very near the firm's research and development laboratory.

As development of the product or service becomes successful, dramatic growth of production and profitability occurs. The firm has a temporary monopoly in the market, and demand-led prices for the new product or service will create excess profits. In this stage (super profit), standardization of production begins to take place, involving a greater number of routine laborers than previously, and the average cost per unit produced will begin to drop. As a result, production begins to decentralize from the research and development center.

In stage three (normal profit), other organizations enter the market with similar products, and price competition can be intense as the market approaches saturation. Mass standardized production is now the norm as cost-cutting becomes imperative. The trend toward decentralization becomes accelerated and the role of the professional/technical worker largely diminishes.

Stage four (normal-plus and normal-minus profit) and stage five (negative profit) are both post-saturation stages. In the former, profit levels can drop even further due to the greatly increased competition or can rise slightly via successful oligopolization. The latter stage is usually where

production will cease. The product becomes obsolete, and the firm takes absolute losses on production.

Nonroutine and innovative activities of the firm, such as research and development, corporate and regional headquarters functions and marketing operations, need to be located in core regions of developed nations as they have a high dependence on skilled labor (Malecki, 1986). These divisions of the organization cannot thrive in all locations in space as the availability of labor skills varies by nation, region and city (Kim, 1987; Walker, Storper, 1981).

These higher order functions often remain with or very near the corporate headquarters in metropolitan areas or in other metropolitan areas near other parts of the firm (Clark, 1981; Erickson and Leinbach, 1979). Due to rapid technological and market changes, they require a high quality and quantity of day-to-day information concerning competition, suppliers and customer needs. While there is a trend toward shorter production runs and more innovative products, which requires interaction of research and development with manufacturing, production and research activities remain on the whole largely separate in purpose and location. This "flexible" production, therefore, needs the same large-city skilled labor as research and development (Arnold, Bernard, 1989; Malecki, 1991; Schoenberger, 1988). Thus, a transportation and communication infrastructure is a requirement for firms when locating nonroutine activities.

Location Criteria of Various Parts of the Firm

A recent survey of Fortune 500 firms clearly indicates that the various parts of the firm have different locational requirements (Corporate Site Selection for New Facilities, 1989). It examines location and relocation criteria of the firms and separates the information into two general categories: 1) manufacturing/processing plants and 2) company facilities. The category of manufacturing/processing plants includes assembly plants, processing plants, extraction plants and warehouse/distribution centers, while the company facilities category includes corporate headquarters, regional headquarters, branch offices, sales offices and branch office processing.

Table 2.1 shows the ten most important factors in selecting locations for manufacturing/processing plants as identified by the study. The criteria mostly relate to costs. Reduction or minimization of labor costs, taxes, transportation costs and land prices are high-priority considerations for these facilities. It is evident that small cities or, in some cases, rural areas in depressed economic regions would be ideal choices (Goldfarb, Yezer, 1987; Heenan, 1991).

The study also found that the South Atlantic region of the United States (North Carolina, South Carolina, Georgia and Florida) was the most popular location choice for

TABLE 2.1
TEN MOST IMPORTANT FACTORS IN SELECTING LOCATIONS FOR MANUFACTURING/PROCESSING PLANTS

Easy access to trucking services	79%
Easy access to domestic markets, customers and clients	74%
Cost of labor	74%
Ample area for future expansion	73%
Easy availability of electricity	71%
Community receptivity to business and industry	70%
Reasonable government/state and or local corporate tax structure	68%
Fair-market property costs	67%
Availability of skilled workers	64%
Extent of unionization	64%

Source: Corporate Site Selection For New Facilities, The Time Inc. Magazine Company, 1989.

manufacturing/processing plants in the past five years and will continue to be the favorite for the next five years. Lower taxes, cost of living and relative absence of unionization add to the attractiveness of this region to firms. The South Atlantic was followed by the East South Central region (Kentucky, Tennessee, Alabama and Mississippi) and the West South Central region (Arkansas, Louisiana, Texas and Oklahoma) in that order. Atlanta, Memphis and Dallas (in rank order) were the most popular urban areas chosen for location by those firms not desiring a small city or rural location.

The attraction of the South has been evident for some time. An earlier study of change in manufacturing employment by state from 1967 to 1972 showed the greatest gains in manufacturing employment in North Carolina (100,000), Texas (78,000), Florida (58,000), Tennessee (49,000) and Georgia (44,000) (Moriarty, 1980). Indeed the "Selling of the South" for manufacturing operations began in the 1930s (Cobb, 1980; 1984).

The ten most important factors in selecting locations for company facilities, a group that includes nonroutine corporate functions (as determined by the Fortune 500 study), are listed in Table 2.2. Here cost considerations largely give way to access to markets and the supply of professional labor as well as adequate transportation facilities.

TABLE 2.2
TEN MOST IMPORTANT FACTORS IN SELECTING LOCATIONS FOR COMPANY FACILITIES

Easy access to domestic markets, customers and clients	73%
Easy access to airport	62%
Efficient transportation facilities for people/employees	59%
Availability of affordable housing	55%
Availability of technical or professional workers	54%
Facilitates access to prospective clients	52%
Urban/metropolitan location	50%
Cost of living	48%
Reasonable government/state and/or local corporate tax structure	48%
Fair-market property costs	48%

Source: Corporate Site Selection For New Facilities, The Time Inc. Magazine Company, 1989.

Face-to-face, nonroutine communication both within and outside of the firm is a vital part of the work of professional employees. Even though communication technology has made phenomenal advancements in recent years, there are times when there is no viable alternative or substitute for an on-site visit. Firms desire frequent contact with their clients and markets to respond quickly to their changing needs. Within the firm, management officials, research scientists and engineers and other administrative service professionals often need to interact with workers in other facilities of the organization to deal with problems and new innovations as quickly as possible. Consequently, frequent air travel between the various facilities of the firm is quite common for these employees (Coffey, Polese, 1989).

A comparison of the top location criteria determined by the study for the various types of company facilities is revealing (Table 2.3). Most of the lists are identical in content with only slight changes in rank order of the criteria.

The back office/processing category, however, is noticeably different. This activity, traditionally associated with the headquarters location, is now largely moving away from central urban locations to, at the very least, suburban locations where land costs are lower (Ady, 1986; Coffey, Polese, 1987; Nelson, 1986). The nature of the work--processing data and paperwork--can be classified as routine

TABLE 2.3
FIVE MOST IMPORTANT FACTORS IN SELECTING LOCATIONS FOR VARIOUS TYPES OF COMPANY FACILITIES

Back Office/Processing Location

1) Availability of skilled workers
2) Availability of unskilled or semi-skilled workers
3) Efficient transportation facilities for people/employees
4) Easy access to domestic markets, customers and clients
5) Cost of labor

Branch Office/Regional Headquarters Location

1) Easy access to domestic markets, customers and clients
2) Facilitates access to prospective clients
3) Availability of technical or professional workers
4) Availability of skilled workers
5) Easy access to airport

Corporate Headquarters Location

1) Availability of technical or professional workers
2) Easy access to domestic markets, customers and clients
3) Easy access to airport
4) Availability of skilled workers
5) Efficient transportation facilities for people/employees

Sales Office Location

1) Easy access to domestic markets, customers and clients
2) Facilitates access to prospective clients
3) Easy access to airport
4) Efficient transportation facilities for people/employees
5) Availability of technical or professional workers

Source: Corporate Site Selection For New Facilities, The Time Inc. Magazine Company, 1989.

even though it is unrelated to manufacturing in many cases, such as in the finance and insurance sectors. A life cycle from nonroutine to routine work also applies to service tasks.

The South Atlantic region of the nation proved to be the most popular location choice for company facilities as well, followed in rank order by the Pacific (California, Washington and Oregon), the East North Central region (Ohio, Indiana, Michigan, Illinois and Wisconsin) and the Middle Atlantic region (New York, New Jersey and Pennsylvania). Because costs are not the most important factor in locating these facilities, the historically innovative industrial areas of the United States still show up strongly. Atlanta, Chicago and Dallas were the most popular urban areas chosen for location or relocation of company facilities by the firms in the survey.

One important firm facility not singled out by the Fortune 500 study was research and development. Research and development (R&D) employs mainly scientists, engineers and other technicians who are involved in nonroutine, innovative research and testing of new products or production processes for the firm. R&D facilities also have their own set of location requirements such as the availability of professional/technical labor, good transportation accessibility (particularly air) and access to scientific and technical information (Ady, 1986; Browning, 1980; Lund, 1986; Malecki, 1979a, 1979b, 1980a, 1980b, 1981). Most firms will

locate their R&D facility (or at least one such facility if there are several) at or very near the corporate headquarters (Malecki, 1980b).

An earlier study conducted by Dow Jones, Inc. (Browning, 1980) confirms that the important criteria found in the Fortune 500 survey for the various firm facilities have been important for at least a decade. The results of this study are given in Table 2.4.

Regional Development and Industrial Location

Regional development is greatly dependent on the location decisions of firms (Knapp, Graves, 1989). As the number of acceptable sites for the various firm facilities has increased, competition among cities, states and regions to attract industry has become particularly fierce (Cobb, 1980, 1984; Johnson, 1989). Most nonurban areas have focused on attracting manufacturing branch plants, as have some metropolitan areas in low-wage parts of the nation. Most urban areas, however, are searching for the nonroutine firm facilities to locate in their city (Thompson, 1987). According to Jacobs (1984), these nonroutine activities of the firm are perceived to be more immune to cyclical and structural changes in the economy and are less likely to experience severe job loss or closure in bad economic times.

TABLE 2.4
IMPORTANT LOCATION FACTORS BY FACILITY TYPE

Manufacturing Plant

1) labor availability
2) energy availability
3) good highway infrastructure

Distribution Center

1) good highway infrastructure
2) market accessibility
3) labor availability

Corporate Headquarters

1) good air transportation service
2) good highway infrastructure
3) professional talent availability

Regional Office

1) good air transportation service
2) good highway infrastructure
3) professional talent availability

R&D Facility

1) professional talent availability
2) good air transportation service
3) good highway infrastructure

Source: Browning, 1980.

Professional Workers

The professional labor force is indeed highly mobile and exerts a great deal of influence on corporate location decisions (Buswell, 1983; Knapp, Graves, 1989). Rapid technological change has created a greater need for highly skilled professional workers, thus increasing the significance of professional labor as a location factor (Weiss, 1985). As they are highly educated and career-oriented, they have a greater degree of choice over where they live and work than do unskilled laborers (Cooper, Makin, 1985; Massey, 1984; Storper, Walker, 1983).

Research has shown that professional workers have a strong preference for large urban areas or at least areas within commuting distance of one (Bradbury, 1988; Malecki, 1987). Cities provide a greater choice of jobs, the ability to change jobs without changing residences, employment opportunities for the spouse and greater cultural and recreational amenities (Herzog, Schlottmann, Johnson, 1986; Noyelle, Stanback, 1984). According to a recent study, the dual-career couple has started to exert a great deal of influence over the location decisions of some firms (Bradbury, 1989). Because of professional workers' narrow range of preferred locational characteristics, Buswell (1983) and others state that professional workers are at the same time geographically immobile (Business Week, 1981).

Labor Migration

Studies have shown that migration of laborers is affected by changing economic opportunities (Gentile, Stave, 1988; Greenwood, 1988). Workers leave an area when they feel their economic prospects are greater elsewhere (Goldfarb, Yezer, 1987). Long and Hansen (1979) found that about half of all moves in the U.S. were to take a job or seek out new employment.

Other factors affecting migration are education, occupation, sex and marital and family status (De Jong, Gardner, 1981; Kaufman, 1982). Young, well-educated professional workers are prime candidates for migration (Greenwood, 1981; Gentile, Stave, 1988). They have fewer ties to specific areas and are often required to relocate within their firm to further their careers. Men migrate more often than women, and single workers more often than married (especially those with children) (Gentile, Stave, 1988).

The Large Metropolitan Area

For nonroutine and innovative divisions of the firm, the firm's locational needs and the locational preferences of its professional workers must be considered together. These different sets of priorities both restrict and reinforce one another with the large metropolitan area being the common

solution. Despite the fact that there are negative attributes associated with them (such as higher land costs, taxes and competition for professional labor for the firm, and higher housing costs, congestion, pollution and increasing crime rates for the professional worker), large urban areas are highly attractive to both firms and workers because of agglomerative advantages and high quality of life (Dahmann, 1983).

Agglomeration economies are advantages associated with being in close proximity to markets and services needed by the firm. Sometimes these advantages arise from the organization locating in a specific area, such as Silicon Valley, where their industry or similar industries tend to cluster (localization economies). These advantages can also occur, however, to all firms in all industries in larger metropolitan areas as firms, suppliers and clients interact with one another (urbanization economies) (Scott, 1988a, 1988b; Watts, 1987).

Large urban areas provide the firm with an ample supply of professional workers, suppliers, services, information and important infrastructure (such as airports with frequent air service to a variety of destinations) and facilitate face-to-face contact when necessary (Andersson, 1985; Dorfman, 1983; Malecki, 1987; Oakey, 1985; Scott, 1983). Being located in a large metropolitan area maximizes the opportunities for a firm to find the industrial linkages it needs while minimizing the

cost of seeking out those linkages (Coffey, Polese, 1989; Hoare, 1985).

Large urban areas are attractive to professional workers because they provide a high level of amenities (such as cultural and recreational) which positively affect their quality of life. Cutter (1985) defines quality of life as one's happiness with the physical and social environment based on how well that environment fits one's personal needs and desires. This, of course, is a subjective concept (making it difficult to measure) and can vary greatly from one individual to another (Canter, 1983; Cutter, 1985). Affecting the quality of life image for professional workers are such factors as climate, cultural and recreational amenities, transportation accessibility, higher educational opportunities, quality of health care, crime rates, pollution levels and cost of living (Boyer, Savageau, 1989; Glasmeier, Hall, Markusen, 1984; Herzog, Schlottmann, Johnson, 1986; Hsieh, Liu, 1983; Pennings, 1982).

Professional workers can be more selective about where they live, and do indeed evaluate quality of life factors when making locational decisions (Markusen, Hall, Glasmeier, 1986; Power, 1980). Location is often the most important factor in the rejection of job offers by job-hunting professionals and transfers within the firm (Collie, 1986; Pinder, 1977). For these workers, large urban areas offer greater employment opportunities for themselves and their spouses, the

possibility for changing jobs without changing residences and a generally more satisfying lifestyle.

Conclusion

Professional workers are engaged in nonroutine activities of the firm. These employees have more control over where they live and work than do employees of routine activities. Location of nonroutine activities, therefore, must be a combination of the residential desires of professional workers and the specific needs of the firm. These workers seek places that provide a high quality of life for them and their families. The firm's needs largely relate to good air and ground transportation, access to supplies and markets and, of course, adequate supply of professional labor. Large urban areas provide the solution, however, not all cities are equal. This is particularly the case, for example, in air transportation, which ranked high on the list of locational needs for all nonroutine activities of the firm. Airline hub cities have a much greater variety of nonstop destinations and more frequent departures from their airports than nonhubs. What follows is a discussion of the air transportation industry and network in the United States.

CHAPTER 3
THE DOMESTIC AIRLINE INDUSTRY

Introduction

Since the deregulation of domestic airlines in 1978, a tremendous degree of change has occurred in almost every aspect of the air travel industry in the United States. As the industry became deregulated, network structures, fares, enplanement levels and service quality were greatly affected. Many new carriers have come and gone (such as Air Florida, Midway and People's Express), and several older, established carriers (such as Eastern, Pan Am and Braniff) have disappeared as well. The first part of this chapter deals with the deregulated industry and its evolution thus far. The second part describes the hub-and-spoke network structure, which is largely a post-regulation phenomenon, and looks at changes in the location and use of hub cities by the air travel industry.

The Deregulated Airline Industry

For 40 years the domestic airline industry in the United States was regulated by the federal government under the Civil

Aeronautics Board (CAB). Beginning in 1938, regulation by the CAB was considered necessary in order to protect and ensure the success of the industry. The CAB originally also set safety standards, a task which was later (in 1958) delegated to the Federal Aviation Administration (FAA) (Bailey, Graham, Kaplan, 1985; Brown, 1987; Meyer, Oster, Morgan, Berman, Strassman, 1981). The CAB had the power to decide if new carriers could enter the air transportation business, to tell carriers what particular routes they could fly, to regulate fares, to award government subsidies to carriers who were forced to fly nonprofitable routes to smaller cities, and to control mergers and acquisitions (Bailey, Graham, Kaplan, 1985; Brenner, 1988; Brown, 1987; McIntosh, Goeldner, 1990). For example, if a carrier wanted to increase its fare between Newark and St. Louis, to begin scheduled service between Memphis and Charlotte or to discontinue service to Tulsa, it was required to have CAB approval.

During the 1970s, many economists and politicians began to argue that regulation was no longer necessary. It was increasingly felt that the U.S. airline industry was mature and that government intervention was creating a very inefficient system (Bailey, Graham, Kaplan, 1985; Brown, 1987; Cates, 1978; Cooper, Maynard, 1972; Snow, 1977). Removing the regulatory barriers, it was further argued, would force the industry to become competitive, bringing about a more efficient and affordable transportation system to the American

traveler (Meyer, Oster, 1987). Proponents of deregulation agreed that many changes would occur early in the era of deregulation that would resemble chaotic instability of the industry but, with time, things would stabilize and the cost and quality of air service would greatly improve in the competitive environment (Goetz, Dempsey, 1989).

The Airline Deregulation Act of 1978 was signed by President Carter and called for a gradual removal of government control over domestic air transportation, with the exception of safety standards (under FAA supervision) and merger and acquisition approval (monitored by the Department of Transportation). A gradual phaseout was recommended to ease the transition to perfect competition in the industry and, by the end of 1984 (when the CAB was dissolved), the phaseout was completed. Following the lead of the U.S., deregulation of air transportation (or at least partial deregulation) has been put in action in a few other western countries, such as Canada and the United Kingdom (Graham, 1990).

A major goal and promise of deregulation was that the cost of domestic air travel in the United States was to become more affordable to the average American. This was supposed to occur because carriers would now compete with one another for business. Two or more carriers would be flying nearly identical routes as they could now choose where they would fly. Also, new airlines were allowed to form at will, which

would eliminate the near monopolistic situation of the larger carriers with respect to total market share of U.S. passengers. The contestable market theory of air transportation held that the mere threat of a new entrant in a market would keep fares down (Leigh, 1990).

During the early 1980s, it appeared that these predictions were realized (Graham, Kaplan, Sibley, 1983; Maraffa, Finnerty, 1988; Rose, 1981). Fares dropped dramatically, allowing more people to afford air travel than ever before, and over 100 new airlines, mostly small commuters, began operation (Goetz, Dempsey, 1989). The latter part of that decade, however, saw unexpected changes that have caused some to question the wisdom of deregulation (Bauer, Zlatoper, 1989; Business Week, 1986, 1988b, 1988c; Leigh, 1990; Morrison, Winston, 1989). In fact, discussions of at least partial reregulation are starting to grow (Kuttner, 1989; Rose, Dahl, 1989).

Many of the new carriers that were supposed to challenge the dominant market shares of the major carriers, unfortunately, were short-lived. Despite the fact that new carriers were successful in the early years of deregulation in reducing the share of revenue passenger miles of the larger airlines, in the long run most all were squeezed out (Goetz, Dempsey, 1989). It is unlikely that there will be a lot of new airlines entering the industry to replace them, as

investor confidence in new airline ventures has lessened considerably (Dempsey, 1987; Rose, Dahl, 1989).

These new smaller carriers had several strikes against them from the beginning. For example, the essential infrastructure of gates, terminal facilities and landing slots has been controlled by the major carriers, making it harder to enter new markets. Almost 70% of all U.S. airports have no gates at all that could be leased to new carriers--although space may sometimes be sublet from other carriers (Hardaway, 1986). Because of their greater buildup of capital, the major carriers have a higher chance of surviving fare wars, and they have used this power to drive both new airlines and old, nearly bankrupt carriers out of business. For those small carriers that did not arrange marketing agreements with the large carriers, much of their business was taken away by the latter due to frequent flyer program loyalty (particularly by business travelers) (Toh, Hu, 1988) and computerized reservation systems made available to travel agencies (Davis, 1982; Oster, Pickrell, 1988).

A glance at the market-share data before and after deregulation shows the trend in market dominance by the largest carriers. At the end of regulation in 1978, the top six airlines controlled 71% of the domestic air traffic. In 1983, that figure dropped to 65% due largely to heavy influx of new carriers, but by the end of 1987 it had risen to 79% (Brenner, 1988) and is rising going into the 1990s (Fortune,

1990). Contributing to this rise was the wave of acquisitions and mergers that occurred during the mid 1980s. The larger carriers began to realize that the best way to survive was to increase their market shares and to neutralize their competition by merging with other carriers (Carlton, Kaplan, Sibley, 1983).

The main, and largely unforeseen, problem that has arisen out of the merging has been the increased control gained by individual airlines over travel in and out of certain cities. The merger of Northwest and Republic Airlines, for example, and TWA with Ozark created market shares of over 80% at Minneapolis/St. Paul and at St. Louis for Northwest and TWA, respectively (McGinley, 1989). Between 1985 and 1988, the number of airports served by at least four airlines dropped by 52%, while the number of cities served by only one carrier increased by 25% (Kuttner, 1989). Nearly two-thirds of all route destinations are now near-monopolies (Traffic World, 1988). This dominance has permitted fare increases, rather than the lower fares predicted by deregulation enthusiasts (Bauer, Zlatoper, 1989; Business Week, 1988b). For example, fares out of St. Louis rose twice as fast as the national average after TWA purchased Ozark (McGinley, 1989).

Another change has been the dramatic decline in service to some urban areas. Some cities are simply harder to get to since deregulation, prompting passenger complaints but little response from either airlines or the federal government.

Small cities have been most adversely affected, both in number of nonstop destinations reached from their facility and in seating capacity (Chan, 1982; Ivy, 1991; Kiel, 1989; Maraffa, Kiel, 1985; Warren, 1984). Airlines have often replaced larger jet aircraft with commuter turboprop planes with less seating capacity on existing routes. Out of 522 small cities that received scheduled commercial air service in 1978, 62% experienced a decline in flight frequency, and nearly 30% of those experienced complete loss of service (Goetz, Dempsey, 1989).

Perhaps the most important issue to passengers is safety of air travel. This has become a major public issue because of the seemingly high number of accidents and mechanical failures of aircraft reported during the past decade. Government statistics lead one to believe that air travel is actually safer in the deregulated skies. Compared with the decade prior to deregulation, jet accidents through 1987 declined by 36%, while the number of fatalities from air crashes declined by 40% (Moses, Savage, 1988). What such data do not show, however, is that the number of near-accidents has been on the rise because of delayed mechanical attention of aircraft and increased congestion, both in the air and along runways due to the competitive nature of the deregulated industry. The number of near-accidents has risen from 568 in 1980 to 1056 in 1987 (Moses, Savage, 1988).

According to the Department of Transportation, the amount spent on aircraft maintenance dropped 30% during the first six years of deregulation (Valente, McGinley, 1988). Moreover, a survey of commercial airplane pilots revealed that almost half believe that their companies defer maintenance of their fleets too long. In addition, the average age of the industry's jets increased by 21% since 1979, with more than half of the jets in service being 16 years or more old in 1988 (Valente, McGinley, 1988). Older fleets typically require more maintenance and repairs than do newer aircraft.

The general consensus of the flying public is that the quality of air service has greatly declined since deregulation. A recent survey of consumers found that 50% felt that such service had declined significantly, while under 20% expressed feelings of improvement. The FAA has reported a soaring number of consumer complaints against the airlines (Consumer Reports, 1988). Deregulation and the resulting network geography of the major carriers have not delivered the promised benefits to all cities and passengers alike (Anderson, Kraus, 1981; Ippolito, 1981). As already mentioned, small cities, on the whole, were adversely affected in terms of seating capacity, fewer non-stop choices and less frequent service. However, many large cities that were not selected as hubs by major airlines (such as New Orleans, Buffalo, and Louisville) have experienced service decline--particularly in the number of non-stop destination choices

reached from each city. In terms of flight frequency, destination choice and ticket prices, residents of cities chosen as a hub by more than one carrier (such as Chicago, Dallas/Ft. Worth, and Atlanta) have probably benefited most from deregulation. Because they are hub cities, they offer a multitude of non-stop destination choices at various times during the day. Having more than one carrier using an airport as a major transfer hub creates competition along many non-stop routes, therefore, keeping fares competitively lower. For example, while the national average annual fare change at hub airports from 1985 to 1988 was a growth of 4%, Atlanta (which served as a hub for Eastern and Delta during that period) experienced a growth of only 1.5% (McGinley, 1989).

The 1980's saw great instability in the industry, and the 1990's (thusfar) are showing no signs of stabilization. Many airlines are still in financial trouble (Continental, America West and TWA are operating under bankruptcy protection as of early 1992). Soaring oil prices, the current recession and intensifying competition from the three giants of the industry (American, United and Delta) are the main sources of the problem (Business Week, 1991a, 1991b, 1991c, 1991d, 1991e, 1991f; Fortune, 1990). Now that over a decade has passed since deregulation, it is increasingly clear that air travelers will likely pay much more for lower quality, less convenient and perhaps more risky transportation by the U.S. airines.

The Hub-and-Spoke System

The hub-and-spoke system currently in place in the U.S. airline industry is largely a product of deregulation. It is the new structure adopted by most airlines to compete more effectively. The major carriers created hubs at strategic regional points in their air networks so travelers from numerous origins (spokes) could be routed into the hub city and then connected with a flight to their final destinations (Business Week, 1988a). The hub-and-spoke structure cuts costs by creating greater overall efficiency with more occupied seats. Route planners, therefore, approach monthly scheduling differently today than prior to deregulation, as such planning is now more important to the profitability of the company than previously (Pollack 1977, 1982).

What few hubs that existed in the regulated era had a slightly different function than hubs today. Chicago, Denver and St. Louis, for example, were used to serve long-haul, east-west markets which used aircraft that did not have transcontinental capabilities (Lopuszynski, 1986). Thus, these cities were set up as transfer points for coast-to-coast traffic. Because of CAB control over routes flown, it would have been difficult for an airline to set up a hub-and-spoke network prior to deregulation.

The deregulated era saw many true hubs develop that acted as collection points for travelers from many origins, sending

them off to many destinations. This new system, along with increased cooperation and code-sharing between major carriers and commuter carriers, made a much greater on-line (same carrier) city-pair matching available to air travelers (Oster, Pickrell, 1988).

The first true hub in this sense was developed by Delta Airlines in Atlanta, and actually was in place before degregulation (Lewis, Newton, 1979). Delta dominated traffic in and out of Atlanta for decades and gradually added more and more service as the years passed. It was the model system copied by other airlines as deregulation forced them towards greater efficiency in order to compete. Figure 3.1 shows the major hub cities (in mid-1991) of the largest carriers.

Much has been written on the positioning of hubs in the air transportation network (Bauer, 1987; Grove, O'Kelly, 1986; Kanafani, Ghobrial, 1985; Lopuszynski, 1986; O'Kelly, 1986a, 1986b; Toh, Higgins, 1985). What makes one city likely to be chosen as a hub over another city? In general, the very largest cities have been favored over medium-sized cities, and eastern cities over western cities. In fact, several cities have been chosen as hubs by more than one carrier, such as New York City, Chicago, Denver and Dallas.

The early trend of choosing the largest cities of the nation as hub cities eventually died as these airports became overly congested. Not only was safety an issue, but delayed flights, overuse of infrastructure, little room for expansion

FIGURE 3.1
HUB CITIES OF THE MAJOR U.S. AIRLINES: 1991

and oversaturated markets plagued some of the hubs. Carriers began to look for medium-sized cities as their transfer points. Often these were strategically located near one of the large, congested hubs to give travelers a pleasant alternative to places like Chicago O'Hare. Piedmont Airlines, later acquired by USAir, made an early success by choosing Charlotte as its southeastern hub, allowing passengers to bypass chronically congested Atlanta's Hartsfield (Davis, 1982). Many other carriers followed Piedmont's lead and expanded their air networks by adding new hubs. This explains, for example, American's new hubs at Nashville and Raleigh/Durham. Competition among airports for hub selection by a major carrier has become intense. The expanded service creates big business for the chosen facility and city, and airport planning boards are more aggressive now than in the past (Barrett, 1987; Butler, Kiernan, 1987; Insight, 1988).

Lopuszynski (1986) has identified some common characteristics of hub cities. It is an ex post facto list that looked at hub cities already in use to find similarities among them. Most hubs were found to contain several of the following characteristics: 1) a sizeable population force with strong business and commercial opportunities 2) a good geographic location with respect to other population centers, physical terrain and weather patterns 3) good airport facilities with adequate room for expansion of gates and runways 4) a strong economy and balanced workforce 5) air

service competition at a minimum acceptable level 6) avoidance of existing major hubs.

While the hub-and-spoke strategy has created greater overall efficiency and cost-cutting benefits for the airlines, the very essence of the system creates problems of congestion, environmental problems such as noise and air pollution, strain on infrastructure and overworked air traffic controllers.

The hub-and-spoke system requires that airlines concentrate many incoming and outbound flights during a narrow time frame to maximize the number of city-pair combinations that can be served. The resulting congestion has been too much for most airports to handle. For example, Atlanta's Hartsfield International Airport has an optimum capacity of 21 arrivals every 15 minutes, as determined by the FAA; however, 32 arrivals were recently scheduled by the airlines between 9:00 a.m. and 9:15 a.m. (Morganthau, 1987). At Chicago's O'Hare, 42 departures were scheduled between 7:00 a.m. and 7:15 a.m., despite a capability to deal safely and efficiently with only 23 (Morganthau, 1987). Increases in the frequency of flights since 1978 at several hubs have been quite large. Baltimore (+94.2%), Dallas/Ft. Worth (+52.2%), Houston (+85.1%), Minneapolis/St. Paul (+60.1%) and Salt Lake City (+51.9%) grew by more than half between 1978 and 1984, while flight frequencies more than doubled at Charlotte (+134.2%) and Newark (+114.2%) (Report on Airline Service, 1984).

Another problem of the hub-and-spoke strategy has been the reduction in the number of nonstop flights from cities other than hub cities. For many city pairs it now takes much longer en route because virtually all flights are routed through at least one hub (Goetz, Dempsey, 1989). The opportunity cost of time is a factor that many travelers consider important. In general, small cities and some of the large spoke cities have often ended up worse off than they were prior to deregulation as they have lost some (and in a few cases all) nonstop service to cities that now have to be reached through hubs (Bauer, 1987; Ivy, 1991).

The advantage for hub-city residents of a large number of nonstop destinations is counterbalanced with some disadvantages. These passengers generally pay much higher fares and have less choice of carriers for most destinations than was the case prior to deregulation (Bauer, 1987; Borenstein, 1989; McGinley, 1989; Toh, Higgins, 1985). Single carrier dominance (Table 3.1) and higher fares are the price paid by residents for greater flight frequency and nonstop destination choice. Hub cities have been hit the hardest with fare increases since their residents are, in effect, subsidizing longer haul passenger fares. Passengers flying from Norfolk to Kansas City through USAir's Charlotte hub, for example, would likely be charged the same fare as passengers travelling on USAir from Charlotte to Kansas City only. Today, flights originating at or departing for hub cities are

TABLE 3.1
SINGLE CARRIER DOMINANCE AT HUBS

city	airport code	1978	1990
Atlanta	ATL	40.8%	53.9%
Baltimore	BWI	26.2%	71.5%
Charlotte	CLT	66.1%	91.1%
Chicago	CHI	27.6%	35.5%
Cincinnati	CVG	34.9%	77.9%
Cleveland	CLE	57.6%	38.7%
Dallas	DFW	36.3%	48.8%
Dayton	DAY	35.3%	74.8%
Denver	DEN	25.9%	42.2%
Detroit	DTW	23.6%	65.4%
Honolulu	HNL	37.5%	35.5%
Houston	HOU	24.6%	50.4%
Las Vegas	LAS	34.9%	48.6%
Los Angeles	LAX	26.2%	17.8%
Memphis	MEM	33.5%	53.6%
Miami	MIA	36.4%	18.3%
Minneapolis	MSP	30.1%	75.3%
Nashville	BNA	27.1%	57.5%
New York	NYC	20.4%	18.0%
Newark	EWR	28.2%	48.9%
Orlando	MCO	43.4%	30.5%
Philadelphia	PHL	28.0%	46.3%
Phoenix	PHX	26.6%	43.5%
Pittsburgh	PIT	51.3%	83.0%
Raleigh/Durham	RDU	59.4%	65.1%
St. Louis	STL	34.6%	74.3%
Salt Lake City	SLC	37.4%	76.4%
San Francisco	SFO	42.4%	29.1%
Seattle	SEA	31.8%	20.6%
Washington, D.C.	DCA	24.3%	23.4%

Source: Calculated from Airport Activity Statistics of Certified Route Air Carriers, U.S. Department of Transportation, Federal Aviation Administration, 1978, 1990.

priced up to 50% more than they would have been had deregulation not occurred (Stockton, 1988). Comparison of one-way fares on selected pairs indicate increases from 1978 to 1988 (in constant dollars) ranging from 28% to 495%, with an average increase of well over 200% (Goetz, Dempsey, 1989).

Conclusion

Deregulation has had a much greater impact on the domestic airline industry than anyone anticipated. Major changes in service and connectivity have occurred in the U.S. air transportation network. Small cities, and even large cities not chosen as hubs, have experienced declines in flight frequency and nonstop destination choice. Hubs have grown tremendously in these areas, but fares have skyrocketed and carrier choice along most routes has lessened. However, not all hubs are alike. The next chapter will look at different types of hubs and discuss hub intensity and connectivity.

CHAPTER 4
VARIATIONS IN HUB SERVICE IN THE DOMESTIC AIR TRANSPORTATION NETWORK

Introduction

A hub is generally defined as a central collection point or node in a transportation system or network. Usage of the term, however, has become particularly applied in the air transportation industry of the United States, largely since deregulation and the advent of the hub-and-spoke system discussed in the previous chapter. In reviewing air transportation literature and data sources (both academic and popular), one encounters the word frequently. Close scrutiny of places labeled as air hubs, however, reveals that not all hubs are equal in the service they offer, in either intensity or connectivity. In fact, some hubs are vastly different from others. Such variations can make the work of the air transportation researcher problematic. This chapter will identify different types of air hubs based on existing usage of the term by the airlines and the Federal Aviation Administration, and explore variations in hub intensity and connectivity within the domestic air transportation network.

The FAA Hub

The initial usage of the word "hub" in the air transportation industry was designated by the Civil Aeronautics Board (now disbanded), and continued by the Federal Aviation Administration (FAA). The FAA classifies all communities with scheduled commercial air service as one of four types of hub, and categorizes each hub based on its share of the nation's annual enplanements. Data for multiple-airport cities (like Chicago and Dallas) are usually summed to represent a community total.

Large hubs, such as Atlanta and St. Louis, represent at least 1.0% of the nation's total annual enplanements. New Orleans and Norfolk, for example, are classified as medium hubs since their share of total U.S. annual enplanements is between .25% and .99%. Communities that represent between .05% and .24% (like Richmond, VA) are classified as small hubs, while non-hubs (such as Gainesville, FL) enplane less than .05% of the nation's total passengers (Airport Activity Statistics of Certified Route Air Carriers, 1990).

Deregulation of the U.S. Airline Industry

As discussed in the previous chapter, the Airline Deregulation Act of 1978 forced the industry into a competitive market situation. While airlines were adjusting

to the new environment, their network geography (node-linkage association) was changing accordingly. Flow efficiency and cost-reduction were made higher priorities. It became increasingly clear that concentrating flights at one or more key regional nodes in their air transportation networks would raise the seat-occupancy levels, thus maximizing the usage of aircraft. Such concentration would also maximize the number of on-line (same carrier) city-pair matchings available to passengers. These central nodes typically offer non-stop service to most every large and medium-sized city in the nation and to smaller cities within the local region of the node. Numerous arrivals and departures are scheduled within a short time frame to allow the connections. This intense type of system has become known as a "hub-and-spoke" network, and now dominates U.S. air transportation. Table 4.1 lists the U.S. hubs as designated by the major domestic carriers. The list was compiled by consulting the fall 1991 schedules and route maps of the carriers, and was confirmed by telephone inquiry to each airline's public relations department. Not included in Table 4.1 are a few cities labeled by some carriers as mini-hubs. These are large cities that do not serve as major transfer points within any airline's network, but do offer some nonstop service (more than other spoke cities) on an individual carrier (for example, Northwest operates a mini-hub at Milwaukee and USAir uses Kansas City as

TABLE 4.1
FALL 1991 HUB CITIES OF THE MAJOR U.S. CARRIERS

city	carrier(s)	non-local traffic
Atlanta	Delta	67.60%
Baltimore	USAir	38.19%
Charlotte	USAir	74.19%
Chicago	American, Midway, United	50.34%
Cincinnati	Delta	53.86%
Cleveland	Continental	24.13%
Dallas/Ft. Worth	American, Southwest	60.04%
Dayton	USAir	48.04%
Denver	Continental, United	50.19%
Detroit	Northwest	38.73%
Honolulu	Continental, United	31.72%
Houston	Continental, Southwest	32.61%
Las Vegas	America West	22.27%
Los Angeles	Delta	40.34%
Memphis	Northwest	62.92%
Miami	American, Pan Am	25.20%
Minneapolis	Northwest	47.76%
Nashville	American	40.96%
New York/Newark	Continental, Delta, TWA	21.87%
Orlando	Delta, United	13.75%
Philadelphia	USAir, Midway	22.04%
Phoenix	America West	32.80%
Pittsburgh	USAir	60.64%
Raleigh/Durham	American	61.84%
St. Louis	TWA	55.33%
Salt Lake City	Delta	60.25%
San Francisco	United	24.40%
Seattle	Northwest	28.84%
Washington	United	20.03%

Note: Since the compilation of this list, Midway and Pan Am Airlines have ceased operations, and USAir has planned the closing of its Dayton hub in 1992.

Sources: Hub lists were obtained from the Fall 1991 schedules and route maps of the major carriers. Transfer percentages were supplied by the U.S. Department of Transportation for the year ending 1990. Percentages were not separated in multiple-airport communities.

such). This service was built up to meet travel demand in markets that some airlines considered to be underserved.

Hub-and-Spoke Growth and Development

The first domestic hub-and-spoke hubs chosen by individual airlines were at airports that were already used by carriers as connection or terminus points for long-haul, east-west traffic using aircraft that did not have transcontinental capabilities (Lopuszynski, 1986). These pre-deregulation connecting airports were in the larger cities in the U.S., and as such, generated high levels of local traffic. Individual airlines tended to focus their early hub-and-spoke strategies on those large-city connecting airports in which they already controlled most of the scheduled departures. Most of these airports were already well-connected (with non-stop service) to other large cities in the nation. The hub-and-spoke hubs were created as the carriers simply added many more flights to many more destinations or spokes (particularly medium-sized and small cities) at these facilities to build up connectivity and create greater overall efficiency and market control at the hub. In some cases, particular airports were selected by more than one carrier as a hub-and-spoke hub. American and United, for example, both created hubs at Chicago O'Hare, while Atlanta became a major transfer city for Delta and the now-defunct Eastern.

As these initial connecting hubs became saturated with traffic, other (often medium-sized) cities were chosen as transfer points, as new airlines developed and as older airlines expanded their networks. Charlotte, Raleigh/Durham and Nashville, for example, were developed as hubs around Atlanta offering travelers a less-congested alternative in the Southeast. Today, the largest carriers have as many as four or five hubs scattered throughout the nation. One can divide the list of hubs from Table 4.1 into two broad categories: 1) hubs that were important connecting airports prior to deregulation (although much less intensely connected than today), and 2) hubs that achieved important transfer status after deregulation (Table 4.2).

Service Variations

Closer examination of the cities on the hub list, however, reveals vast differences among the airports' service levels and functions. In fact, not all of the locations listed in Table 4.1 really function as hub-and-spoke hubs. As mentioned, hubs of this type are characterized by many non-stop flights to cities of all sizes. Also, the very nature of the network structure suggests that a good portion of the traffic at these hubs should be nonlocal, if the hub is indeed successful as a transfer point. Some of the airports labeled by the major carriers as air hubs do not have true

TABLE 4.2
PRE AND POST-DEREGULATION HUB CITIES
(1991)

PRE-DEREGULATION HUBS:

Atlanta	Minneapolis
Chicago	New York/Newark*
Dallas/Ft Worth	Philadelphia
Denver	Pittsburgh
Honolulu	St. Louis
Houston	San Francisco
Los Angeles	Seattle
Miami	

POST-DEREGULATION HUBS:

Baltimore (1983)	Memphis (1984)
Charlotte (1981)	Nashville (1986)
Cincinnati (1987)	Orlando (1989)
Cleveland (1989)	Phoenix (1983)
Dayton (1982)	Raleigh/Durham (1987)
Detroit (1984)	Salt Lake City (1982)
Las Vegas (1985)	Washington, D.C. (1986)

* Newark International Airport on its own would be classified as a post- deregulation hub. People's Express (eventually consumed by Continental Airlines) developed hub facilities there in 1981.

Source: Hub information was obtained from a series of surveys of airports and airlines by mail and telephone (in mid-1991). The years next to the post-deregulation hubs indicate the year of development as a major transfer hub as determined by the airport in question.

hub-and-spoke functions, at least not at the same level of intensity as others.

A few of the cities listed as hubs function as feeder points for a specific carrier's international network. They are usually well connected with the individual airline's other domestic hub cities, and also offer nonstop service to and from the largest cities (largest markets) in the nation. Thus, they do act as transfer points for the carrier, but on a less intense level. They are certainly not important transfer points within the domestic air transportation network. Los Angeles, Miami, New York (JFK), Seattle and San Francisco are all international gateway hubs instead of hub-and-spoke hubs for domestic air networks. These peripherally located cities have a lower percentage of nonlocal traffic at their airports than almost every other hub on the list (Table 4.1). This means that a smaller proportion of their traffic is changing aircraft at their facility bound for a different final destination. In addition, the particular carrier(s) claiming hub status at each of the five facilities listed above offer rather limited nonstop service from them, especially in comparison to other domestic hub-and-spoke hubs. Table 4.3 looks at nonstop connections between hubs listed in Table 4.1 and FAA hub airports of various sizes. It is clear that some hubs on the list (particularly the international gateway hubs) are not as well connected to cities (spokes) of all sizes as are many of the other hubs.

TABLE 4.3
NONSTOP DOMESTIC CONNECTIONS ON ALL CARRIERS BY FAA HUB-TYPE
(FALL 1991)

airports	large	medium	small	non	total
ATL	27	23	33	24	107
BWI	22	16	10	19	67
CLT	24	18	27	25	94
CHI	27	29	35	27	119
CVG	27	17	19	7	70
CLE	22	13	7	3	45
DFW	27	26	25	23	102
DAY	17	6	7	6	36
DEN	25	19	16	24	84
DTW	25	16	14	14	70
HNL	11	2	3	5	21
HOU	26	16	10	9	61
LAS	22	12	3	1	38
LAX	27	17	5	14	63
MEM	23	10	14	20	67
MIA	20	10	4	4	38
MSP	26	13	11	30	81
BNA	24	14	18	14	70
NYC*	26	17	17	17	78
MCO	22	13	8	4	47
PHL	23	18	12	19	72
PHX	24	16	6	9	55
PIT	25	20	20	33	98
RDU	15	12	16	12	55
STL	27	22	16	19	83
SLC	18	12	7	17	55
SFO	26	14	8	14	62
SEA	22	7	4	14	47
DCA	25	17	23	19	84

Source: <u>OAG Pocket Flight Guide</u>, November 1991.

*Includes Newark

An emerging category is the destination hub. These are cities that are popular travel destinations, and as such offera great deal of nonstop service to and from large and medium-sized cities around the nation to meet the high demand. Orlando, Las Vegas and Honolulu fall into this classification (although Honolulu also serves as an international connecting point). All three generate comparatively low nonlocal traffic rates (Table 4.1), and are not well connected to cities of varying size (Table 4.3). Few passengers flying into these cities are transferring to other domestic locations, and these are mainly via commuter carriers from the local area. Some of the international gateway hubs could be considered destination hubs as well (like Los Angeles and New York) due to their popularity as travel destinations.

Hub Connectivity

Because today's hubs (and the carriers operating them) basically compete with one another for transfer traffic, the success of a hub usually depends on how well connected it is to other nodes in the U.S. air transportation network. The hub airport (and carrier) that has a greater variety of nonstop service to different sized cities in all parts of the nation is in a better position to attract passengers and control markets. Atlanta competes with Charlotte in the Southeast, for example, and Dallas, Houston and Denver

basically compete in the West for the same transfer passengers. What follows is a discussion of the measurement of hub connectivity using a graph theoretical approach. Graph theory allows one to view the network as a topological map comprised of nodes (points of economic concentration) and linkages (routes that connect two nodes). Thus, it shows network connectivity in a relative sense. This technique illustrates the strength (in terms of connectivity) and attractive power of the hubs listed in Table 4.1.

Analyzing Hub Connectivity

One graph theoretic method of measuring the connectivity or accessibility of a node begins with the construction of a binary matrix that represents the network abstracted as a graph (Lowe, Moryadas, 1975; Taaffe, Gauthier, 1973). It is a square matrix in which the number of rows and columns each represent the number of nodes in the transportation network. The horizontal rows represent origin nodes, while the vertical columns represent destination nodes. Both rows and columns, of course, contain the same list of points. The cell entries of the matrix are assigned a value of either one or zero. A value of one shows the presence of a direct (nonstop) linkage between specific nodal pairs, while a value of zero indicates the absence of such a linkage. Nodes are not considered to be connected to themselves; therefore, the principal diagonal of

the matrix (all i,i entries) contains zeroes as cell entries. Thus, the connectivity matrix (C1) shows first order connections in a transportation network.

A vector of values that can be used as a crude measure of nodal accessibility is obtained by summing the individual rows or columns of the matrix. The higher the summed row or column value of the node, the greater the accessibility of the point. This accessibility index on its own is of limited usefulness, however, because we are often interested in both direct and indirect connections.

The number of indirect connections in a network can be determined by powering the original connectivity matrix (Lowe, Moryadas, 1975; Taaffe, Gauthier, 1973). The matrix (C1) can be multiplied by itself (resulting in matrix C2) to look at second order or two-step connections (connections that pass through an intermediate node) in the network. Likewise, the third order connectivity matrix (C3) is obtained by multiplying matrix C1 by matrix C2. To take all indirect connections into account, the matrix should be powered to the Nth order (CN), where N represents the diameter of the transportation network. (The diameter is defined as the shortest topologic distance between the two most distant nodes in the network.) At this stage, all zero elements disappear from the matrix indicating that all nodes are connected. Summing the matrix C1 with the powered matrices shows the total accessibility of each node within the network

(accessibility matrix). The individual rows or columns of this accessibility matrix (T) can be summed to yield the gross vertex connectivity for each node in the network.

Early researchers using the above-mentioned technique (Garrison, 1960; Pitts, 1965), discovered that while powering the matrix did give the maximum number of alternative paths in a network, a number of redundancies (passing through the same node more than once) were included in the final accessibility matrix (T). This was particularly the case for nodes that were directly connected in the original connectivity matrix (C1).

Another criticism by Garrison (1960) was that all linkages should not be considered equal in importance. The more indirect the linkage, the less it should add to the gross vertex connectivity number. He introduced a procedure in which a scalar number (s) that takes on a value between zero and one is multiplied by the accessibility values in each matrix powered according to the order of the matrix [$T=sC1+s^2C2+s^3C3+...+s^NCN$]. The real problem lies in assigning the scalar value (Garrison's scalar of .3 was assigned arbitrarily). The technique, however, does lessen the importance of indirect connections relative to direct connections and at the same time reducing the impact of redundant paths. A new scalar method will be introduced in the next section.

Results

The above-mentioned technique was applied to a study set of 117 nodes to measure accessibility within the U.S. domestic air transportation network. These nodes were all U.S. urban areas (excluding 4 Hawaiian cities not well connected to the U.S. mainland) that are classified by the FAA as a large (total of 28), medium (total of 29) or small (total of 60) hub (Table 4.4). The purpose was to find out how well connected each of the airline hubs listed in Table 4.1 was to cities of various sizes scattered around the nation. Due to the fact that there are several hundred FAA non-hubs, they were excluded to keep the size of the matrix manageable (117 x 117). The connectivity data for the original matrix (C1) was abstracted from the November 1991 issue of the OAG Pocket Flight Guide.

The matrix was ordered to the third power (C3). At that point, all of the non-zero elements disappeared from the matrix cells. The diameter of this network is three because one can fly between any domestic city pair in the study set in three or fewer flight segments (due to the intense hub-and-spoke structuring). The summed accessibility indices for each metropolitan area for matrices C1, C2, C3, and T are given in Appendix A. The accessibility indices for each hub (from matrix C1 and T) and their respective rankings are given in Table 4.5. Note that the hub rankings for matrix C1 (direct

TABLE 4.4
FAA HUBS

FAA Large Hubs

Atlanta	Miami
Baltimore	Minneapolis/St. Paul
Boston	New York/Newark
Charlotte	Orlando
Chicago	Philadelphia
Dallas/Ft. Worth	Phoenix
Denver	Pittsburgh
Detroit	St. Louis
Honolulu	Salt Lake City
Houston	San Diego
Kansas City	San Francisco
Las Vegas	Seattle
Los Angeles	Tampa
Memphis	Washington, D.C.

FAA Medium Hubs

Albuquerque	New Orleans
Austin	Norfolk
Buffalo	Oklahoma City
Cincinnati	Ontario
Cleveland	Portland
Columbus	Raleigh/Durham
Dayton	Reno
El Paso	Rochester
Ft. Myers	Sacramento
Hartford	San Antonio
Indianapolis	San Jose
Jacksonville	Syracuse
Kahului	Tucson
Lihue	Tulsa
Milwaukee	West Palm Beach
Nashville	

TABLE 4.4--continued

FAA Small Hubs

Akron/Canton	Kailua-Kona
Albany	Knoxville
Allentown	Lexington
Amarillo	Lincoln
Anchorage	Little Rock
Baton Rouge	Louisville
Billings	Lubbock
Birmingham	Madison
Boise	Melbourne
Brownsville	Midland
Burlington	Mobile
Cedar Rapids	Moline
Charleston (SC)	Myrtle Beach
Charleston (WV)	Omaha
Chattanooga	Palm Springs
Colorado Springs	Pensacola
Columbia	Portland
Corpus Christi	Providence
Daytona Beach	Richmond
Des Moines	Roanoke
Eugene	Saginaw
Fort Wayne	Santa Barbara
Fresno	Sarasota
Grand Rapids	Savannah
Greensboro	Shreveport
Greenville	Sioux Falls
Harrisburg	South Bend
Hilo	Spokane
Huntsville	Tallahassee
Islip	Toledo
Jackson	Witchita

TABLE 4.5
ACCESSIBILITY INDICES FOR MATRICES C1 AND T

airports	matrix C1	rank	matrix T	rank
ATL	83	2	93552	2
BWI	48	16	69753	15
CLT	69	4	83769	4
CHI	92	1	97950	1
CVG	63	8	82183	7
CLE	42	23	63749	20
DFW	79	3	88668	3
DAY	30	28	47457	28
DEN	60	10	71207	13
DTW	56	11	76515	10
HNL	12	29	20889	29
HOU	52	14	69597	16
LAS	37	25	53701	25
LAX	48	17	68678	17
MEM	47	18	63525	21
MIA	34	26	55436	23
MSP	51	15	70247	14
BNA	56	12	74299	12
NYC*	61	9	81114	9
MCO	43	21	65272	18
PHL	53	13	74469	11
PHX	46	19	62542	22
PIT	65	5	83524	5
RDU	43	21	54992	24
STL	64	7	81844	8
SLC	38	24	47692	27
SFO	46	20	64887	19
SEA	33	27	48591	26
DCA	65	6	82696	6

*Includes Newark

connections only) and matrix T (direct and indirect connections) are slightly different (Spearman's rank order coefficient of .979). Twelve of the cities (mostly ranked in the top ten) remain at the same rank, but ten rise in the rankings (Baltimore, Cincinnati, Cleveland, Detroit, Miami, Minneapolis, Orlando, Philadelphia, San Francisco and Seattle) while seven fall (Denver, Houston, Memphis, Phoenix, Raleigh/Durham, St. Louis and Salt Lake City) when indirect as well as direct connections are taken into account (matrix T). The rankings show an eastern bias because more of the 117 nodes in the original matrix (C1) were located in the East or Midwest than in the western half of the United States.

Scalar multiplication was also performed on the original and powered matrices. Table 4.6 shows the accessibility matrix (T) indices using a variety of scalars. While the magnitude of difference between the cities, of course, changes as the scalar changes, the specific rank order of the cities remains constant (concordant). It is also the exact rank order of the unscaled accessibility matrix T (Table 4.5).

A more refined weighting technique assigns a different scalar value to each of the 117 nodes in the network. This weight is based on the individual node's share (from the last column in Table 4.3) of total direct connections in the network (1,969). One advantage of this weighting procedure is that it allows the FAA nonhub connections to be taken into account, albeit in an indirect way. The results of this

TABLE 4.6
ACCESSIBILITY INDICES OF MATRIX T WITH DIFFERENT SCALARS

airports	s=.25	s=.3	s=.5	s=.75
CHI	1615	2755	12447	41543
ATL	1542	2630	11886	39676
DFW	1464	2497	11274	37614
CLT	1380	2354	10642	35527
PIT	1376	2347	10613	35424
DCA	1362	2324	10508	35074
CVG	1354	2310	10443	34856
STL	1350	2303	10405	34718
NYC*	1337	2282	10310	34407
DTW	1260	2150	9723	32453
PHL	1228	2094	9466	31589
BNA	1225	2090	9444	31516
DEN	1180	2010	9064	30219
MSP	1161	1980	8938	29807
BWI	1150	1962	8866	29588
HOU	1149	1961	8854	29530
LAX	1136	1937	8742	29146
MCO	1077	1838	8302	27693
SFO	1075	1832	8262	27539
CLE	1051	1793	8104	27042
MEM	1049	1789	8080	26951
PHX	1036	1765	7963	26544
MIA	916	1562	7053	23523
RDU	906	1546	6989	23325
LAS	889	1516	6838	22793
SEA	807	1374	6192	20629
SLC	791	1348	6075	20244
DAY	783	1336	6035	20134
HNL	347	592	2664	8871

*Includes Newark

weighting procedure are given in Table 4.7. The rankings are slightly different from both the original connectivity matrix C1 (Spearman's rank order coefficient of .979), and the unweighted matrix T (Spearman's rank order coefficient of .951). Cincinnati and St. Louis, for example, are closely ranked in matrices C1 and T from Table 4.5, but the weighting procedure requiring the calculation of a different scalar for each individual node puts a greater difference in rankings between these two cities (Table 4.7). This is because St. Louis is connected to a greater total number of cities (once nonhubs are included), and therefore, fares better in the final ranking of accessibility numbers.

Connectivity and Intensity Classification Scheme

Using the accessibility information from Table 4.7 and transfer traffic information from Table 4.1, the following classification scheme measuring hub strength was derived. Hubs are classified as super, major--type A, major--type B, moderate--type A, moderate--type B, minor--type A, minor--type B or non-hub (Table 4.8). The eight classifications were made using a one-dimensional iterative partitioning clustering method using the accessibility numbers given in Table 4.7 (Aldenderfer, Blashfield, 1984).

Chicago, Atlanta and Dallas are super hubs. They are the top ranked for accessibility in all of the matrices that were

TABLE 4.7
ACCESSIBILITY INDICES OF INDIVIDUALLY WEIGHTED NODES

airports	weight	accessibility number	rank
ATL	.054	22.76	2
BWI	.034	5.53	15
CLT	.048	15.13	5
CHI	.060	31.24	1
CVG	.036	7.57	11
CLE	.023	2.24	24
DFW	.052	19.87	3
DAY	.018	1.05	28
DEN	.043	10.23	8
DTW	.036	6.96	13
HNL	.011	0.25	29
HOU	.031	4.69	18
LAS	.019	1.39	26
LAX	.032	4.89	17
MEM	.034	5.18	16
MIA	.019	1.34	27
MSP	.041	8.70	10
BNA	.036	6.84	14
NYC*	.040	9.45	9
MCO	.024	2.50	23
PHL	.037	7.18	12
PHX	.028	3.44	20
PIT	.050	16.49	4
RDU	.028	3.02	21
STL	.042	10.78	7
SLC	.028	2.72	22
SFO	.031	4.36	19
SEA	.024	1.94	25
DCA	.043	11.44	6

*Includes Newark

TABLE 4.8
HUB STRENGTH CLASSIFICATION SCHEME

SUPER HUBS	Atlanta, Chicago, Dallas
MAJOR HUBS--TYPE A	Charlotte, Denver, Pittsburgh, St. Louis
MAJOR HUBS--TYPE B	New York, Washington, D.C.
MODERATE HUBS--TYPE A	Cincinnati, Memphis
MODERATE HUBS--TYPE B	Baltimore, Detroit, Houston, Los Angeles, Minneapolis, Nashville, Philadelphia
MINOR HUBS--TYPE A	Raleigh/Durham, Salt Lake City
MINOR HUBS--TYPE B	Cleveland, Orlando, Phoenix, San Francisco
NON-HUBS	Dayton, Honolulu, Las Vegas, Miami, Seattle

Note: Type A hubs have a transfer (non-local) passenger percentage of 50% or greater, while the non-local percentage for type B hubs is less than 50% (table 4.1).

constructed, and are indeed in a class by themselves. Because they are large in population, more centrally located in the nation than many of the other U.S. mega cities, and each an important transfer point for more than one carrier for several years (until early 1991, the now defunct Eastern Airlines had hub operations at Atlanta's Hartsfield), these cities have been the major pivot centers for air transportation for more than a decade. Each has a non-local (transfer) traffic base of over 50% of its total enplanements. They have a clear advantage over peripheral hubs like Miami, New York and Los Angeles in that they are more proximal to a greater number ofnodes in all parts of the country. These hubs are also operated by one or more of the financially strongest carriers in the nation (American, Delta, United) helping to make possible more flights to more destinations.

Major hubs--type A are cities with high accessibility numbers and transfer passenger percentages of over 50% (excluding the super hubs). Charlotte, Pittsburgh, St. Louis and Denver make up this category. While the major hubs--type B have high accessibility numbers as well, their non-local traffic base is less than 50% of the total traffic at their facility. For these hubs (New York and Washington, D.C.), this is more a reflection of the city in question's popularity as a final destination (due to sheer population size), and the fact that both are multiple airport cities, than a reflection on the service offered at the airports.

The moderate hubs have medium-ranging accessibility numbers and include almost one-third of the hubs from table 4.1. Only Memphis and Cincinnati have non-local passenger percentages of over 50% (type A), although some of the type B moderate hubs are near that proportion.

Minor hubs--type A and minor hubs--type B have low accessibility numbers. Again, type A hubs have non-local passenger percentages of over 50% (Salt Lake City and Raleigh/Durham, for example), while type B hubs (like San Francisco and Orlando) do not.

Miami, Honolulu, Seattle, Las Vegas and Dayton make up the non-hub category. These are cities (largely destination or international gateway hubs) with very low accessibility numbers and transfer percentages below (in most cases well below) 50%. Dayton, a USAir hub, is being pulled down from that status in early 1992. These cities are in no way comparable to the higher domestic connectivity and major transfer role played by the other hubs from Table 4.1.

Conclusion

This chapter brings to light possible confusion in the usage of the term hub, from the FAA definition (which has nothing whatsoever to do with transfer or connecting status) to the various service levels of the airline definition. The hub-and-spoke phenomenon of the post-regulation period has,

without a doubt, drastically changed air transportion in the United States. The accessibility matrix (T) gives us a good indication of which hubs are the most highly connected to more of the nation, and therefore, which are more powerful in controlling market shares. This might be used to help understand why some carriers are more financially successful than others in an industry that has been very unstable for more than a decade. The next chapter will investigate the relationship between changes in professional employment growth rates and changes in air transportation connectivity in the 60 largest MSAs in the United States.

CHAPTER 5
CHANGES IN CONNECTIVITY AND PROFESSIONAL EMPLOYMENT LOCATION

Introduction

This chapter investigates a number of research questions concerning changes in air service connectivity, professional employment and corporate location. Data were collected on the 60 largest metropolitan areas in the United States in 1988, listed in Table 5.1. The MSAs (metropolitan statistical areas) include a mix of hubs and nonhubs from every region of the country, although there is a bias toward the east. The total number of employees, number of administrative and research and development employees, airport enplanements and nonstop destinations available (of the 60-city study set) were collected for these cities in each year from 1978 through 1988. The starting point of the analysis is 1978 since that was the last fully regulated and fairly stable year for the airline industry. The analysis continues through 1988 to show progressive changes and help identify lag effects in the relationship between changes in connectivity and professional employment.

TABLE 5.1
60 LARGEST METROPOLITAN AREAS OF THE U.S.
(1988-in thousands)

New York/Newark CMSA	(NYC)	18,120
Los Angeles CMSA	(LAX)	13,770
Chicago CMSA	(CHI)	8,181
San Francisco CMSA	(SFO)	6,042
Philadelphia CMSA	(PHL)	5,963
Detroit CMSA	(DTW)	4,352
Boston CMSA	(BOS)	4,110
Dallas/Ft. Worth CMSA	(DFW)	3,766
Washington, D.C. MSA	(WAS)	3,734
Houston CMSA	(HOU)	3,641
Miami/Ft. Lauderdale CMSA	(MIA)	3,001
Cleveland CMSA	(CLE)	2,769
Atlanta MSA	(ATL)	2,737
St. Louis MSA	(STL)	2,467
Seattle CMSA	(SEA)	2,421
Minneapolis/St. Paul CMSA	(MSP)	2,388
Baltimore MSA	(BWI)	2,342
San Diego MSA	(SAN)	2,370
Pittsburgh CMSA	(PIT)	2,284
Phoenix MSA	(PHX)	2,030
Tampa/St. Petersburg MSA	(TPA)	1,995
Denver CMSA	(DEN)	1,858
Milwaukee CMSA	(MKE)	1,562
Kansas City MSA	(MCI)	1,575
Cincinnati CMSA	(CVG)	1,449
Portland CMSA	(PDX)	1,414
Sacramento MSA	(SMF)	1,385
Norfolk MSA	(ORF)	1,380
Columbus MSA	(CMS)	1,344
San Antonio MSA	(SAT)	1,323
New Orleans MSA	(MSY)	1,307
Indianapolis MSA	(IND)	1,237
Buffalo CMSA	(BUF)	1,176
Providence CMSA	(PVD)	1,125
Charlotte MSA	(CLT)	1,112
Hartford CMSA	(BDL)	1,068
Salt Lake City MSA	(SLC)	1,065
Rochester MSA	(ROC)	980
Memphis MSA	(MEM)	979
Nashville MSA	(BNA)	972
Orlando MSA	(MCO)	971
Louisville MSA	(SDF)	967
Oklahoma City MSA	(OKC)	964
Dayton MSA	(DAY)	948
Greensboro MSA	(GSO)	925
Birmingham MSA	(BHM)	923

TABLE 5.1--continued

Jacksonville MSA	(JAX)	898
Albany MSA	(ALB)	851
Richmond MSA	(RIC)	844
Honolulu MSA	(HNL)	838
West Palm Beach MSA	(PBI)	818
Austin MSA	(AUS)	748
Scranton MSA	(AVP)	731
Tulsa MSA	(TUL)	728
Raleigh/Durham MSA	(RDU)	683
Allentown MSA	(ABE)	677
Grand Rapids MSA	(GRR)	665
Syracuse MSA	(SYR)	650
Tucson MSA	(TUS)	636
Las Vegas MSA	(LAS)	631

Note: The three-letter code listed after each city is the airport code for the city as assigned by the FAA. Some cities on the list are served by more than one airport. In these cases, one code is chosen to represent the urban area as a whole, but includes total destinations and flows from all airports in the metropolitan area.

Source: Statistical Abstract of the United States, 1990.

Research Questions

This chapter investigates how changes in connectivity are related to changes in employment growth of those highly active in nonroutine communication within and outside of the firm. It is assumed that hub cities have a much greater selection of nonstop destinations from their airports plus a higher rate of connectivity change as the hub develops, and as such, have a greater (and growing) concentration of scientists, engineers and administrators in their workforce than nonhubs.

The study will also determine which change occurs first. The potential demand for air service could attract one or more airlines to set up hub operations with abundant nonstop service in the city, thus making it an attractive choice for companies to locate or relocate such activities. Alternatively, the demand could have already existed, with an airline merely stepping in to fill the void in service. The changes could also occur simultaneously as new economic growth regions are identified by the airline industry and other corporations.

If an airline's choice of a hub does make that city likely to draw more company headquarters, regional offices and research and development labs and their workers to the city (or induce such facilities to leave nonhub cities), the study will determine how long it takes for the flow to begin. If the effect is in the other direction, the study will determine

how long it takes the airline to respond (with increased service levels) to the potential market growth brought on by the new addition to the urban area's employment structure.

Finally, the study will look for regional and hierarchical biases. Hubs in some areas may show a stronger relationship between the two variables than hubs in other parts of the nation, and hubs with higher population totals could show a stronger or weaker relationship between connectivity change and employment change than smaller-sized hubs.

The Labor Data

The professional labor data were collected from the County Business Patterns series published by the U.S. Census Bureau. It is an annual publication with volumes for all 50 states, the District of Columbia and Puerto Rico. Unfortunately, this labor information is not published on a consistent basis for metropolitan areas as a whole. The series records the number of employees per economic sector (based on SIC codes) by county in the states. Within each sector, a separate classification is reserved for professional workers. The publication refers to these workers as administrative and auxiliary employees, defined as personnel working in central administration offices and auxiliary establishments such as research labs and financial services.

While the category also includes some warehouse and distribution employees (nonprofessional labor), County Business Patterns was found to be the best source available for obtaining raw numbers of professional workers in a specific area.

The number of professional workers for each of the 60 cities in the study set was obtained by summing the administrative and auxiliary employees for each sector in each county included in the MSA (as determined by the U.S. Census Bureau) (Appendix B). These data were collected for all 60 cities from 1978 (the beginning of the study period) through 1988 (the most current data available at the time of the collection process). The results are given in Appendix C.

Table 5.2 shows the 20 MSA's (from the study set) with the greatest number of professionals in their workforce at the end of that period (1988). It is not surprising that the largest cities in the nation in population rank high on this list. Most of these 20 MSA's lie in the traditional manufacturing belt, although a few southern and western urban areas made the list as well.

Table 5.3 indicates the flow pattern of administrative and auxiliary jobs and workers. This table shows the U.S. cities that experienced the greatest increase in the number of professional workers from 1978 to 1988. While a few of the large metropolitan areas of the Northeast made this list (such as Boston, New York/Newark and Philadelphia), the southern and

TABLE 5.2
MOST ADMINISTRATIVE/AUXILIARY EMPLOYEES: 1988

	MSA	number of professionals	population rank
1)	New York/Newark	462,305	1
2)	Los Angeles	193,284	2
3)	Chicago	183,688	3
4)	Boston	139,258	7
5)	Detroit	136,782	6
6)	Philadelphia	136,055	5
7)	San Francisco	120,469	4
8)	Dallas/Ft. Worth	109,966	8
9)	Houston	95,362	10
10)	Minneapolis/St. Paul	83,141	16
11)	Atlanta	81,958	13
12)	Washington, D.C.	64,363	9
13)	Cleveland	63,586	12
14)	St. Louis	58,350	14
15)	Providence	55,189	34
16)	Seattle	43,944	15
17)	Cincinnati	40,221	23
18)	Pittsburgh	39,973	19
19)	Miami/Ft. Lauderdale	36,602	11
20)	Columbus	33,304	29

Source: Calculated from County Business Patterns, U.S. Census Bureau, 1990.

TABLE 5.3
LARGEST GROWTH IN ADMINISTRATIVE/AUXILIARY EMPLOYEES: 1978-1988

	MSA	+ change
1)	Boston	68,528
2)	New York/Newark	55,239
3)	Dallas/Ft. Worth	49,976
4)	Atlanta	39,931
5)	San Francisco	31,222
6)	Washington, D.C.	28,310
7)	Providence	28,292
8)	Philadelphia	22,989
9)	Minneapolis/St. Paul	21,459
10)	Houston	21,236
11)	Seattle	18,496
12)	Miami/Ft. Lauderdale	17,697
13)	Los Angeles	16,575
14)	Charlotte	13,967
15)	Orlando	13,965
16)	Jacksonville	12,273
17)	San Diego	10,488
18)	Richmond	10,315
19)	Columbus	9,843
20)	Phoenix	9,821

Source: Calculated from County Business Patterns, U.S. Census Bureau, 1980, 1990.

western parts of the United States are strongly represented, including cities such as Charlotte, Richmond, Jacksonville, Orlando and Phoenix which did not make the list in Table 5.2. Some of the cities in Table 5.2 experienced a loss of administrative and auxiliary workers during the period in question. These are listed in Table 5.4. Almost all of these cities are in the traditional manufacturing belt. Tulsa and Oklahoma City, however, are oil-producing cities whose fortunes changed during the early and middle 1980s as the price for oil dropped significantly, and the economy of oil states (particularly Oklahoma and Texas) suffered.

Table 5.5 gives a regional analysis for the 60 metropolitan areas in the study set. It shows the total and average administrative and auxiliary employment growth of the study set cities within each region. These regions are the traditional divisions of the nation as defined by the U.S. Census Bureau (Figure 5.1). The Northeast still shows up strongly with the South being a near second.

Perhaps of greater interest to a discussion of professional workers in urban locations is Table 5.6. It shows the 20 cities with the highest percentage of administrative and auxiliary workers as a proportion of their total employment for 1988 (constructed from Appendices C and D). Many of the larger cities on the list in Table 5.2 either drop off this list or appear at a lower ranking on the list. Some new cities appear that were absent from Table 5.2, such

TABLE 5.4
ADMINISTRATIVE/AUXILIARY EMPLOYMENT LOSS: 1978-1988

MSA	change
Detroit	-27,340
Pittsburgh	-12,179
Albany	-4,094
Indianapolis	-2,216
Baltimore	-1,999
Tulsa	-1,674
Oklahoma City	-1,258
Chicago	-592
Buffalo	-367

Source: Calculated from County Business Patterns, U.S. Census Bureau 1980, 1990.

TABLE 5.5
ADMINISTRATIVE/AUXILIARY GROWTH BY REGION: 1978-1988

region	number of MSA's	employee growth	MSA average
Northeast	12	170,993	14,249
North Central	12	36,919	3,077
South	24	243,392	10,141
West	12	100,311	8,359

Source: Calculated from County Business Patterns, U.S. Census Bureau, 1980, 1990.

TABLE 5.6
HIGHEST PERCENTAGE OF ADMINISTRATIVE/AUXILIARY AS A PORTION OF TOTAL EMPLOYMENT: 1988

	MSA	percentage of professionals
1)	Tulsa	8.76
2)	Detroit	7.75
3)	Allentown/Bethlehem/Easton	7.38
4)	Minneapolis/St. Paul	7.16
5)	Greensboro/Winston/Salem	7.14
6)	Houston	7.08
7)	Dallas/Ft. Worth	6.58
8)	Richmond	6.53
9)	Atlanta	6.44
10)	Rochester	6.07
11)	Columbus	5.96
12)	New York/Newark	5.86
13)	St. Louis	5.83
14)	Cleveland	5.74
15)	Dayton	5.73
16)	Philadelphia	5.72
17)	Cincinnati	5.58
18)	Chicago	5.43
19)	Boston	5.20
20)	Charlotte	5.18

Source: Calculated from <u>County Business Patterns</u>, U.S. Census Bureau, 1990.

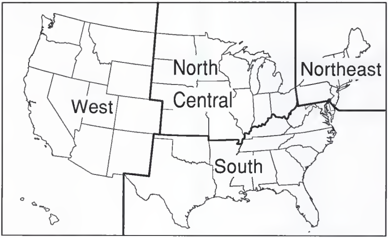

FIGURE 5.1
CENSUS REGIONS OF THE UNITED STATES

as the Greensboro/Winston-Salem and Tulsa metropolitan areas. Because it readily identifies cities with strong administrative and auxiliary functions, using the percentage of professional employment in the total labor force isprobably a better indicator of the true administrative and auxiliary cities in the United States.

The Air Service Data

The sources for the air service data were the Official Airline Guide (OAG) and Airport Activity Statistics of Certified Route Air Carriers. Enplanement figures (Appendix E) were extracted from the latter source (published yearly by the Federal Aviation Administration) which records a variety of information about passenger and cargo flow at all domestic airports with scheduled commercial service. The Official Airline Guide is published monthly and gives route schedules of the commercial carriers in the United States. It was the source for nonstop (Appendix F) and other city-pair connection data. Unfortunately, this publication is not widely available because of its cost and the sheer size of each issue (creating storage problems). Back issues of the publication were found at a library (University of North Carolina at Chapel Hill) which saves only one issue from every year (usually, but not always, July). Therefore, connection and schedule data for the various years are from summer schedules of the major

carriers. It should be noted that summer schedules are usually expanded to accommodate extensive vacation travel, and are not representative of the average service offered during the year as a whole.

Data were collected on all 60 cities in the study set for each year from 1978 through 1988. More current air data were available, but the collection process was stopped at 1988 to keep the air data consistent with the available labor data (as discussed in the previous section of this chapter). In communities with multiple airports (e.g. Dallas and Chicago), the individual airport information was combined to obtain a community total. Multiple airport communities are listed in Table 5.7.

The U.S. cities with the highest enplanement (boarded passenger) levels in 1988 are given in Table 5.8 by rank order along with their average number of daily departures and the number of cities in the study set to which they are connected with nonstop air service (59 is the maximum number of nonstops). The list consists of the largest cities in the nation, plus a few popular travel destinations such as Honolulu, Las Vegas and Orlando. It is not suprising that almost all (except Boston) are airline hub cities (Table 4.1). Every city (of the 60 in the study set) grew in enplanement levels from 1978 to 1988 except Louisville (which dropped by 38,163 passengers) and Scranton/Wilkes/Barre (a decline of 16,240) (Appendix E).

TABLE 5.7
MULTIPLE AIRPORT CITIES

Chicago	Midway, O'Hare International
Dallas	Love Field, DFW International
Detroit	Detroit City, Detroit Metro-Wayne County
Greensboro	Greensboro, Smith-Reynolds
Houston	Hobby, Houston Intercontinental
Los Angeles	L.A. International, Hollywood/Burbank, Orange County, Long Beach
Miami	Miami International, Ft. Lauderdale
New York City	JFK, LaGuardia, Newark International
San Francisco	San Francisco International, Oakland
Washington, D.C.	Washington National, Dulles International

TABLE 5.8
LEADING ENPLANEMENT CITIES OF THE U.S.: 1988

	city	enplanements	non/stops*	daily departures
1)	New York/Newark	32,820,184	48	957
2)	Chicago	29,770,857	56	1045
3)	Dallas	23,488,986	50	765
4)	Los Angeles	22,836,344	37	743
5)	Atlanta	21,824,125	56	756
6)	San Francisco	15,173,602	28	542
7)	Denver	14,441,817	40	514
8)	Miami	13,360,799	27	399
9)	Washington	11,586,627	49	482
10)	Houston	10,712,269	38	432
11)	Boston	10,141,298	40	316
12)	St. Louis	9,554,454	46	384
13)	Phoenix	9,455,324	31	364
14)	Detroit	9,343,770	43	352
15)	Honolulu	8,396,313	11	230
16)	Pittsburgh	8,378,639	49	345
17)	Minneapolis	8,170,952	40	301
18)	Orlando	7,473,086	38	259
19)	Las Vegas	6,864,803	28	220
20)	Seattle	6,825,513	22	296

Sources: Official Airline Guide, July 1988 and Airport Activity Statistics of Certified Route Air Carriers, 1988.

* number of different non-stop connections of the 60 in the study set

The average number of daily departures (Table 5.8) were calculated by dividing the number of commercial departures scheduled by the airlines during the calendar year 1988 (as recorded by the Federal Aviation Adminstration) by 365. Again, most of the metropolitan areas in the study set saw an increase in the number of daily airplane departures from 1978 to 1988. Los Angeles, Chicago, San Francisco, Houston, Phoenix and Charlotte all saw increases of over 200 daily departures. Eight cities, however, experienced declines. Milwaukee, Grand Rapids, Albany, Scranton/Wilkes/Barre and Birmingham all showed decreases of less than 3 daily departures, while Louisville lost an average of 8 departures, New Orleans an average of 13 and Buffalo an average of 16 daily departures from 1978 to 1988.

Some cities with a higher number of nonstop connections than a few of those listed in Table 5.8 are Cincinnati (43), Charlotte (40), Philadelphia (43), Cleveland (37) and Baltimore (38). They are all hub cities, and as such, are highly connected. Twelve cities in the study set experienced significant increases (10 or more) in the number of nonstop connections available from their airports between 1978 and 1988 (Table 5.9). They are largely post-deregulation hubs (Table 4.2). Fifteen cities, most of them spoke or nonhub cities from the study set, however, experienced reductions in the number of nonstop connections from their facilities. The

TABLE 5.9
GREATEST INCREASES IN NONSTOP CONNECTIONS
1978-1988

	city	increase
1)	Orlando	20
2)	Charlotte	18
3)	Cincinnati	17
4)	Minneapolis	16
5)	Raleigh/Durham	16
6)	Nashville	15
7)	Memphis	14
8)	Phoenix	12
9)	Pittsburgh	12
10)	Salt Lake City	11
11)	Atlanta	10
12)	Baltimore	10

Source: Official Airline Guide, July, 1978 and 1988

Note: of the 60 cities in the study set

most severe decline was felt by Buffalo (7), a city whose economy suffered during the period.

Research Methodology

The analysis in this chapter investigates whether or not changes in connectivity are related to changes in professionalemployment growth or vice versa. To measure the impact of hub selection on this growth, a general hub/nonhub comparison was carried out using all 60 cities in the study set over the 11 year period.

Changes in connectivity were monitored using a derived accessibility index. The yearly connectivity indices for each metropolitan area were compared to changes in professional employment by looking at the average rate of change of each variable from one year to the next. Graphing both rate-of-change values for each hub city over time should give an indication of the relationship between the two variables. The means of the yearly average rates of change for connectivity and professional employment were calculated for each MSA, and a simple correlation analysis was done to determine the statistical relationship between the two. In addition, by separating the data for the MSA's into different groups, regional and hierarchical information was obtained.

To test for a lag structure in the relationship between the variables, times series regression analysis was performed

using the average rates of change for each variable for all years in the study period.

Accessibility Indices

To obtain accessibility measurements to be used in the analysis, binary matrices were constructed for each of the 11 years in the study period (1978-1988). Each 60 X 60 matrix had cell values of either one or zero. A value of one was assigned to the cell if a direct air service connection existed between the particular cities in question. If such a connection did not exist, then the cell was assigned a value of zero.

As discussed in Chapter 4, this simple connectivity matrix (C1), can be used to measure accessibility from a graph theoretic approach. The row values are summed to give the nodality index or gross vertex connectivity number for each node. The larger the nodality index, the greater the relative connectivity. Higher order connections can be taken into account by powering the original connectivity matrix (C1) until all of the zero elements disappear from the resultant matrix. Summing the matrix C1 with the powered matrices (yielding matrix T) allows one to measure total accessibility within the network.

Each matrix was multiplied to the third power. At this point, all zero elements disappeared from the resultant

matrices. Thus, the diameter of each network (from 1978 through 1988) is three. Appendix G gives the yearly accessibility indices for each metropolitan area from matrices C1, C2, C3 and T from 1978 through 1988. It is particularly important in this study to include indirect connectivity effects since business travelers often visit multiple destinations in one trip without necessarily going back through the same hub city between flight segments. The cities (airports) with the highest accessibility indices in 1988 are ranked in Table 5.10.

Employment-Connectivity Relationships

Figure 5.2 compares the average rate of change from one year to the next (from 1978 through 1988) in the number of professional workers (administrative and auxiliary employees) in the labor force in each of the 60 metropolitan areas to the average rate of change in air service connectivity. The rates were calculated from the raw numbers of administrative and auxiliary employees and connectivity indices given in appendices D and H, respectively. A quick glance reveals that the two graphs have the same general trend in the first half of the study period, but no apparent similarity in the latter years. If the two variables are related to (affected by) one another, a change in one seems to bring a near instantaneous change in the other during the early years of the period, with

TABLE 5.10
STUDY SET CITIES WITH HIGHEST ACCESSIBILITY INDICES: 1988

	city	index number
1)	Chicago	53,747
2)	Atlanta	53,386
3)	Dallas	50,158
4)	Washington, D.C.	49,999
5)	New York/Newark	49,887
6)	St. Louis	49,839
7)	Pittsburgh	49,297
8)	Cincinnati	46,562
9)	Detroit	46,193
10)	Charlotte	45,955
11)	Philadelphia	45,403
12)	Minneapolis	43,304
13)	Boston	43,239
14)	Denver	42,651
15)	Cleveland	42,371
16)	Houston	41,649
17)	Orlando	41,623
18)	Los Angeles	41,250
19)	Baltimore	41,109
20)	Memphis	40,628

Source: Appendix G

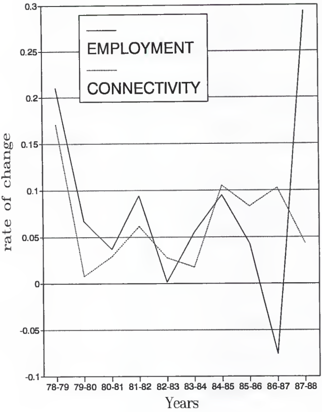

FIGURE 5.2
CHANGE IN PROFESSIONAL EMPLOYMENT VS. CONNECTIVITY

the employment change occurring slightly ahead of the connectivity change. In the latter years, either there is no relationship between the two or possibly a complex lag structure exists.

The data were divided between hubs and nonhubs to compare the different rates of change for both air connectivity and professional employment for each group. Post-deregulation hub cities were considered part of the nonhub group until the year that hub status was achieved (Table 4.2). For example, Baltimore was classifed as a nonhub until 1983, but was switched to the hub category after 1983.

The nonhub connectivity rate of change (Figure 5.3) stays very close to the rate of change for professional employment (practically the same graph), while the hub city connectivity rate (Figure 5.4) stays below the employment rate of change for much of the study period (until the latter years). Indeed, the two lines in Figure 5.4 appear to have little in common. The graphs (Figures 5.3 and 5.4) seem to suggest that a stronger and virtually instantaneous relationship exists between connectivity change and professional employment change for nonhubs than for hub cities.

Figure 5.5 breaks the employment data between hubs and nonhubs. Throughout a fair portion of the study period, professional employment at nonhubs grew by a higher rate than hub cities. The mean of the yearly average rates of professional employment change during the study period for

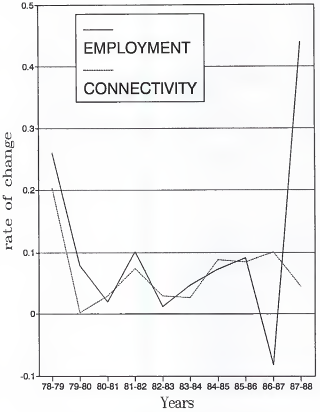

FIGURE 5.3
NONHUB EMPLOYMENT VS. CONNECTIVITY

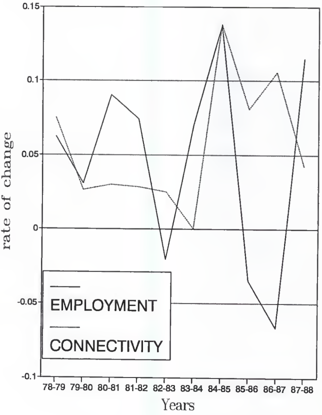

FIGURE 5.4
HUB EMPLOYMENT VS. CONNECTIVITY

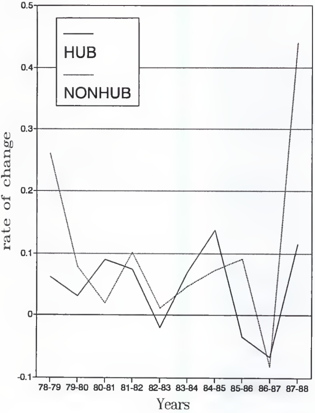

FIGURE 5.5
EMPLOYMENT CHANGE: HUB VS. NONHUB

hubs was 4.58%, while the nonhub mean was 10.38%. Since the hub cities are mainly the largest metropolitan areas in the study, and as such are entering the study period with a larger base and proportion of professional employment in their workforce, their rate of change would be expected to be lower than that of the nonhubs. The graph also illustrates a probable lag structure that exists between employment growth in hub cities and nonhubs, with the hub growth occurring earlier than the nonhub growth. The nonhub growth could be spillover growth from hub cities.

Similarly, the connectivity data were divided between hubs and nonhubs (Figure 5.6). The hub cities have somewhat lower rates of change in connectivity than the nonhubs, particularly in the beginning of the study period. For much of the period, the hub graph lies below the nonhub graph. This is due to the fact that many present-day hubs were also pre-deregulation hubs (Table 4.2) and, therefore, already had a high degree of connectivity compared to other cities. Figure 5.6 suggests that, throughout most of the 11 year period, slight changes in hub connectivity brought greater rates of change (in both directions) in connectivity for the nonhubs (spoke cities). The mean of the yearly average rates of connectivity change for hub cities from 1978 through 1988 was 5.5%, while the non-hub mean was 6.8%.

Notice that towards the end of the study period, however, the average rates of change for both groups are rather equal.

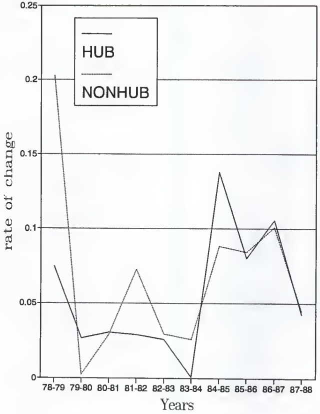

FIGURE 5.6
CONNECTIVITY CHANGE: HUB VS. NONHUB

This suggests that as the air transportation network has become saturated and more stable, any change in the network now affects hubs and nonhubs fairly equally.

Regional Trends

To determine any regional variations in the growth rates, the study set was separated into four different groups. These groups are the traditional regional divisions of the UnitedStates as defined by the Census Bureau (Figure 5.1). The Northeast, North Central and West each have 12 of the 60 metropolitan areas of the study set within them. The remaining 24 cities lie in the South.

Figures 5.7 and 5.8 compare the average rate of change of the number of professional workers in the labor force in the Northeast cities to their rate of change in air service connectivity for hubs and nonhubs, respectively. The connectivity rate of change remains fairly low for this group of cities, with the hub graph never rising above .1 (or 10% growth rate) and the nonhub graph only doing so near the end of the study period. The urban areas of the Northeast are among the largest in population and are major centers of business. As such, they are (and always have been) major market destinations for air travel. Also, the density of major metropolitan areas in the Northeast has contributed to high levels of air service connectivity before and after

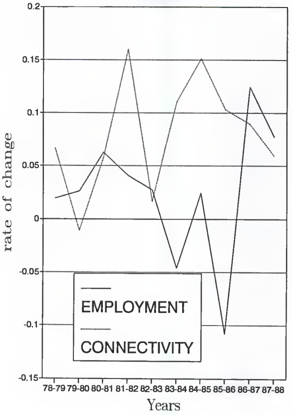

FIGURE 5.7
NORTHEAST HUB RATES OF CHANGE

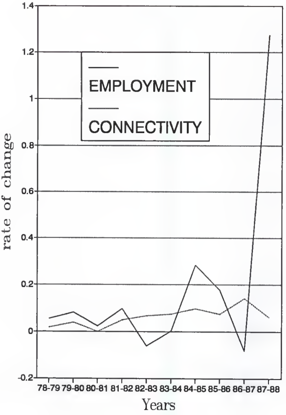

FIGURE 5.8
NORTHEAST NONHUB RATES OF CHANGE

deregulation and the hub-and-spoke intensification. Therefore, the average rate of change in air service connectivity in the Northeast is mainly below the other regions of the U.S., as will be illustrated. Throughout a fair portion of the 11 year period, the nonhub average rate of change has been much more stable than the hub average for the Northeast group of cities.

The average rate of change in professional employment for the Northeast cities is similar to the connectivity rate of change (fairly low), although both hubs and nonhubsexperienced some negative rates of change (employment loss). The meager rate of employment change that exists for most of the study period is in response to a general U.S. trend of professional employment growth away from the traditional manufacturing areas (Northeast and Midwest) of the country as discussed previously. Figure 5.8 shows that the nonhub rate of change recently experienced a sharp rise in the Northeast. Perhaps this contribution shows the importance of being located in the Northeast for nonroutine parts of the firm, but out of (although close to) the large, overly-congested, expensive, crime-ridden cities.

The nonhub graph shows a stronger relationship between employment change and connectivity change, being almost the same graph for much of the study period. In the hub case, there may be a complex lag structure between the two variables.

The rate of change comparisons between professional employment and air service connectivity for the cities in the North Central region (Figures 5.9 and 5.10) are quite different from the Northeast. Both graphs appear less stable than the graphs of the Northeast. In particular, the professional employment lines of both figures are very erratic with wide jumps and drops throughout the study period, indicating a high degree of vulnerability to changing economic fortunes in the region. Both connectivity lines are much more steady, upward-trending graphs with only a few drops in the growth rates. In this region, however, it is the hub group that is more stable and regular in its growth trends, and the hub graph shows a lagged relationship between the two variables, at least during the initial part of the time period.

The graphs of the West (Figures 5.11 and 5.12) have sporadic jumps and drops as well. In this region, however, the nonhub group appears to have been more stable in its growth pattern than the hub cities. Both graphs show apparent lag structures, but on the nonhub graph (Figure 5.12), it appears that the change in connectivity occurs slightly ahead of the employment change (different from the other graphs that indicated lag structures).

The graphs of the South show a great deal of fluctuation in employment and connectivity rates of change (Figures 5.13 and 5.14). Most of the nonhub graph (Figure 5.14) seems to

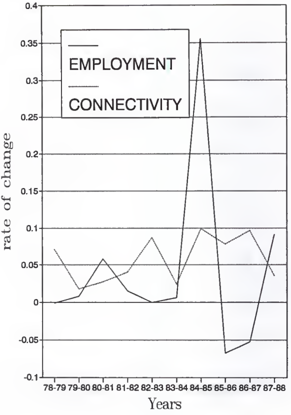

FIGURE 5.9
NORTH CENTRAL HUB RATES OF CHANGE

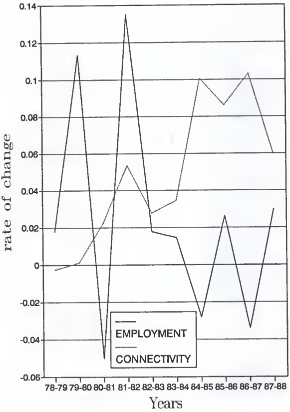

FIGURE 5.10
NORTH CENTRAL NONHUB RATES OF CHANGE

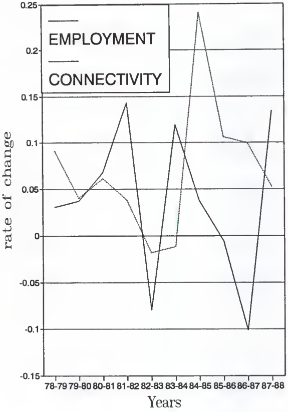

FIGURE 5.11
WESTERN HUB RATES OF CHANGE

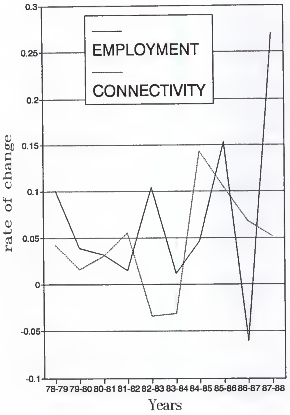

FIGURE 5.12
WESTERN NONHUB RATES OF CHANGE

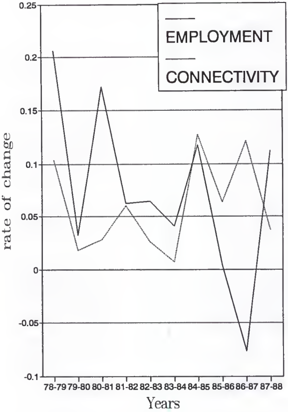

FIGURE 5.13
SOUTHERN HUB RATES OF CHANGE

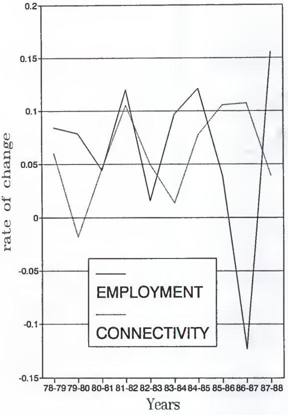

FIGURE 5.14
SOUTHERN NONHUB RATES OF CHANGE

suggest a link between the two variables. The peak growth and decline periods of the two lines occur at virtually the same time during the first part of the period and slightly lagged during the latter part of the period. The trend of the lag suggests that fluctuations in the rate of change of professional employment growth in the non-hubs of the South has an impact on the average rate of change in air service connectivity for the cities. The pattern for the hub group (Figure 5.13) is more complex, but a general downward trend for professional employment rate of change in the hub cities is easily identifiable.

Numerical Analysis

Some simple numerical analysis was conducted using the mean value of the year-to-year rates of change for each of the MSA's in the study set (Table 5.11).

First, a general hub/non-hub comparison was made. Hub cities experienced a mean rate of connectivity change of .0553 (5.53%), and a mean rate of professional employment change of .0458 (4.58%). On the other hand, the nonhub group experienced even higher growth rates of both connectivity (6.79%) and professional employment (10.38%). Most all of the smaller cities (in population size) from the study set fall into the nonhub group. As smaller cities, they are generally coming into the study period with lower base-levels of

TABLE 5.11
MEAN ANNUAL RATE OF CHANGE IN EMPLOYMENT AND CONNECTIVITY: 1978-1988

MSA	employment	connectivity
Albany	3.58%	5.34%
Allentown	6.03%	3.95%
Atlanta	7.78%	4.21%
Austin	11.27%	14.54%
Baltimore	0.66%	5.36%
Birmingham	10.01%	3.07%
Boston	16.75%	5.45%
Buffalo	1.43%	0.37%
Charlotte	7.33%	10.19%
Chicago	0.39%	3.24%
Cincinnati	2.54%	6.85%
Cleveland	2.38%	2.95%
Columbus	5.09%	4.44%
Dallas/Ft. Worth	7.40%	4.82%
Dayton	15.52%	6.65%
Denver	0.46%	4.68%
Detroit	-1.39%	4.25%
Grand Rapids	8.76%	9.06%
Greensboro	7.48%	5.05%
Hartford	2.84%	5.00%
Honolulu	2.85%	11.73%
Houston	3.30%	5.92%
Indianapolis	-0.54%	4.01%
Jacksonville	100.38%	6.52%
Kansas City	1.54%	3.99%
Las Vegas	6.81%	4.74%
Los Angeles	1.79%	2.79%
Louisville	2.42%	3.31%
Memphis	5.02%	6.79%
Miami	8.03%	2.50%
Milwaukee	2.18%	3.54%
Minneapolis	3.17%	7.11%
Nashville	-6.04%	8.00%
New Orleans	1.44%	3.19%
New York/Newark	1.47%	2.99%
Norfolk	1.59%	5.87%
Oklahoma City	-0.27%	1.29%
Orlando	14.60%	9.61%
Philadelphia	2.28%	3.36%
Phoenix	6.18%	7.40%
Pittsburgh	-0.93%	5.73%
Portland	1.39%	2.31%

TABLE 5.11--continued

MSA	employment	connectivity
Providence	8.81%	5.86%
Raleigh/Durham	7.89%	11.42%
Richmond	6.41%	4.61%
Rochester	6.78%	3.56%
Sacramento	7.49%	5.33%
St. Louis	1.74%	4.49%
Salt Lake City	3.30%	7.83%
San Antonio	7.54%	6.64%
San Diego	9.29%	1.70%
San Francisco	3.52%	2.32%
Scranton	0.84%	2.33%
Seattle	9.44%	5.73%
Syracuse	0.93%	5.75%
Tampa	7.02%	2.86%
Tucson	6.61%	6.47%
Tulsa	-0.29%	3.67%
Washington, D.C.	7.14%	2.97%
West Palm Beach	22.84%	8.74%

professional employment and connectivity indices (hence the higher growth percentages).

Second, a regional analysis of the hub city mean growth rates was conducted using the census regions from Figure 5.1. Again, there does not appear to be a relationship between connectivity and professional employment rates of change. Southern hub cities experienced the highest rate of professional employment change (4.85%), followed by the Northeast (4.36%), the West (4.29%) and the North Central hubs (3.52%). In connectivity change, however, it is the group of hubs in the West that lead (6.39%), followed by the South (6.22%), the North Central group (5.43%) and the Northeast hubs (4.03%). The rank order correlation coefficient between the two is exactly zero.

Correlation Analysis

The common method for measuring the degree of association between two variables is the correlation coefficient (Pearson's r). The value of the coefficient will always lie between -1 and +1. A set of variables that are positively correlated (an increase in one variable occurs with an increase in the other) will have an (r) coefficient that lies close to +1. A coefficient that lies close to -1 implies that the variables are negatively correlated (an increase in one variable occurs with a corresponding decrease in the other).

Statistical tests can be run to check that the strength of the linear relationship is significant. Coefficient values that lie close to zero are uncorrelated (no association). This simple analysis, however, does not check for a lagged relationship or association between the variables.

A correlation analysis was performed on the means (of each of the 60 MSAs) of the annual rates of connectivity and professional employment change (from Table 5.11). The correlation coefficient (r) was found to be very close to zero (.010678) and; therefore, uncorrelated. Breaking the data between hubs and nonhubs, the (r) values were still closer to zero than to +1 or -1 (.1371933 for the hub cities and .2402332 for the nonhubs). Again, this test does not check for a lagged relationship between the variables. A regional correlation analysis was not done due to the small sample size of each of the groups.

Hierarchical Analysis of Hub Cities

This subsection looks at the mean of the yearly rates of change for the hub cities from Table 5.11 to see if a hierarchical bias exists in the relationship between connectivity change and professional employment growth. While all of the hub cities in the table experienced positive mean rates of connectivity change during the study period, two cities (Detroit and Nashville) experienced a decline in the

mean rates of professional employment change. San Francisco, Dallas/Ft. Worth, Washington, D.C., Miami, Atlanta, Seattle, Pittsburgh and Dayton had higher mean annual rates of employment change than connectivity change (unlike the other 19 cities).

To examine hierarchical differences in both rates of change, the 27 hubs were placed into one of five groups based on their 1988 population. An iterative clustering procedure was used to identify the members of each group. Table 5.12 shows the five groups (clusters) that were derived, and the mean of the yearly average rates of professional employment and connectivity change are given in Table 5.13. As the average population size of the MSA cluster decreases, the mean annual rate of change tends to increase for both connectivity and professional employment (rank order correlation coefficient of .9). Smaller hub cities (in most cases starting the study period with a lower base level of professional employment and connectivity indices) have experienced higher growth rates than the larger hubs.

However, individual hubs that rank high on the list of professional employment growth rates do not necessarily have correspondingly high-ranking rates of connectivity change (and vice versa). The rank-order correlation coefficient is a rather weak .1624, indicating that no statistically significant relationship exists in the rankings of the two mean growth rates for each hub city.

TABLE 5.12
HUB CLUSTERS BASED ON POPULATION TOTALS

GROUP 1

New York/Newark
Los Angeles

GROUP 2

Chicago
San Francisco
Philadelphia

GROUP 3

Detroit
Dallas/Ft. Worth
Washington, D.C.
Houston

GROUP 4

Miami
Atlanta
St. Louis
Seattle
Minneapolis/St. Paul
Baltimore
Pittsburgh
Phoenix
Denver

GROUP 5

Cincinnati
Charlotte
Salt Lake City
Memphis
Nashville
Dayton
Honolulu
Raleigh/Durham
Las Vegas

TABLE 5.13
MEAN ANNUAL RATE OF CHANGE BY POPULATION CLUSTER: 1978-1988

group number	mean employment change	mean connectivity change
one	1.63%	2.89%
two	2.06%	2.97%
three	4.11%	4.49%
four	5.11%	5.25%
five	5.02%	8.68%

Calculated from Table 5.11

Lag Structure

Visual inspection of some of the graphs discussed earlier in the chapter indicated the possibility of a lagged relationship between the professional employment and connectivity variables. Time series analysis was used to further examine this issue.

Time Series

Time series is a regression technique that checks for a relationship between variables over a fixed and constant interval. There are two types of time series analysis. The first looks at the relationship of variables observed at the same point in time (nonlagged case), while the second relates a current variable to past values of other variables in the model (lagged case). Successfully generated models can be used to explain the past behavior of variables and predict future behavior as well (Ostrom, 1990).

One problem with the lagged time series analysis is the determination of the appropriate lag interval, in other words, how long it may take the variable X_t to affect Y_t. In this case, however, the graphs suggest that if a lag exists, it most likely occurs in one interval. Therefore, a lagged time series analysis (multiple regression with a lagged variable)

was conducted using SPSS/PC+, a statistical package for the IBM personal computer, with the following model formula:

$$Y_t = a + b_0X_t + b_1X_{t-1} + e_t$$

The model was run for six different cases (Figures 5.2, 5.3 and 5.4), and the results are given in Table 5.14. The first model examines the relationship between professional employment and connectivity change for the entire study set, while models two and three deal with the same relationship for hubs and nonhubs, respectively. For each model, two different cases were run switching the professional employment and connectivity rates of change from independent to dependent variables (Table 5.14).

In all six cases, the R^2 value is closer to 0 than to 1, indicating that no strong relationship exists between the dependent and independent variables in the models (Table 5.14). Also, the estimated regressor coefficients (X_t and X_{t-1})are not significant (T-test) at the .95 confidence level for any case. The overall fit of the model (F-test) also fails to be significant at the .95 confidence level in each case. This last test is of great importance. Failure of the F-test indicates that the R^2 and T statistics are not valid (Clark, Hosking, 1986).

Another statistic given in Table 5.14 is the Durbin-Watson number. This statistic looks at the residuals (estimated error terms) generated from regression analysis.

TABLE 5.14
TIME SERIES ANALYSIS

Model 1A	Y=connectivity rate of change for study set X=professional employment rate of change for study set
Model 1B	Y=professional employment rate of change for study set X=connectivity rate of change for study set
Model 2A	Y=hub connectivity rate of change X=hub professional employment rate of change
Model 2B	Y=hub professional employment rate of change X=hub connectivity rate of change
Model 3A	Y=nonhub connectivity rate of change X=nonhub professional employment rate of change
Model 3B	Y=nonhub professional employment rate of change X=nonhub connectivity rate of change

model	R^2	T sig	lag T sig	F sig	D-W
1A	.16	.3933	.3801	.5909	1.69
1B	.04	.6887	.8404	.8782	2.09
2A	.02	.9106	.7829	.9453	1.69
2B	.23	.9384	.9384	.2366	2.26
3A	.29	.2669	.1839	.3570	1.56
3B	.05	.8156	.7190	.8663	1.89

The aim of the Durbin-Watson index is to make sure that no autocorrelation exists among the residuals, which is one of the assumptions of regression analysis. Autocorrelated residuals often occur when important explanatory variables are left out of the regression analysis. If autocorrelation is detected among the residuals, the regression coefficients and R_2 statistic are not valid (Ostrom, 1990).

Durbin and Watson designed a table that gives an upper and lower numerical boundary that varies with sample size and the number of regressors in the model. The generated Durbin-Watson statistic is compared with that critical region. If the value of the statistic is less than the lower boundary listed in the table, then positive first-order autocorrelation exists. If the statistic is greater than the upper boundary, then we fail to reject the null hypothesis that autocorrelation does not exist. When the Durbin-Watson statistic falls within the specified region, the test is considered inconclusive. For the models presented here, the lower boundary for the statistic is given as .408 with the upper boundary being 1.389 (Clark, Hosking, 1986). All of the Durbin-Watson statistics from table 5.14 are above the upper boundary. When a lag structure exists in the model, often the residuals are autocorrelated. The fact that they are not positively autocorrelated for these models indicates that if a lag structure exists, it is rather weak one (Ostrom, 1990).

Conclusion

The analysis of this chapter fails to show a relationship between changes in air service connectivity and professional employment. While some of the graphs seemed to indicate visually that a lagged relationship existed between the two variables, time series analysis failed to verify that relationship statistically. However, a hierarchical bias was shown to exist for hub clusters. Those clusters with smaller average populations had higher average connectivity and professional employment growth rates. The regional information derived was inconclusive. The next chapter will be a summary of the study and an identification of the problems of the data set and the methods of analysis.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Introduction

This study attempted to relate aspects of industrial location theory to connectivity changes that have occurred in the air transportation industry in the United States since 1978. As Chapter 2 stated, certain corporate facilities that employ a great proportion of professional workers are often interested in locating in or near cities that are easily accessible to many other cities or markets. Because these nonroutine employees must be able to quickly move around to clients, suppliers and different parts of the firm, an airport with high-quality service (well-connected and frequent departures) is not only an advantage, but often a necessity for these facilities. This final chapter summarizes the findings of this study and identifies its important contributions as well as its shortcomings.

Summary of Results

The analysis of this study fails to show a significant relationship between changes in air service connectivity and

professional employment in the 60 MSAs in the study set over the period from 1978 through 1988. As stated in Chapter 5, the correlation coefficient between the two variables was far from significant with the relationship for nonhub cities being a little stronger than for hub locations (although still insignificant).

The time series model also failed to show a significant (lagged) tie between professional employment change and connectivity change. This was unexpected because some of graphs that were constructed seemed to indicate a fairly strong lagged relationship of one time period between the two variables.

The analysis failed to show a regional bias. The South was the only region that showed any remote relationship between the two rates of change. The southern group ranked highest for connectivity change, and second highest for professional employment change. The relationship in the South would probably have been even stronger if the oil cities (whose economies declined in the 1980s) in Texas, Oklahoma and Louisiana had not been included in the group.

The tests for a hierarchical bias were clearly the strongest and most interesting from a geographic perspective. Many of the smaller cities in the study set (largely the nonhubs) experienced greater rates of change for both professional employment and connectivity. Even the smaller hubs seemed to experience higher rates of change for both

variables than hubs that belonged to the larger population cluster groups (Table 5.13). Another interesting observation from Tables 5.12 and 5.13 is that the population cluster groups with the lowest rates of change in both professional employment and air service connectivity are largely peripheral cities. This would seem to indicate that more central locations have been preferred both by airlines and by corporations.

Guidelines for Future Research

One of the principal assumptions in the set of research questions addressed in this study appears to have been incorrect. It was assumed that hub cities would have experienced substantially greater rates of connectivity change than nonhubs. While it is true that hub cities have many more flights to many more destinations, the connectivity indices of most of the nonhubs have actually grown by higher percentages as a result of the expansion of the hub-and-spoke system. Nonhubs may be connected to fewer cities today than prior to deregulation, but the cities they are now connected to (hub cities) have much higher connectivity indices than before deregulation. Therefore, the increased connectivity felt by nonhubs is largely indirect.

The biggest shortcoming in the present study is the brief time period. Deregulation and the intensification of the hub-

and-spoke system are fairly recent events. Therefore, only 11 years were available for inspection. Eleven years is not really long enough to do a meaningful time series analysis. A minimum of 30 years is usually recommended (Ostrom, 1990). Also, within those 11 years, the domestic airline industry, and therefore air service connectivity, has been (and still is) rather unstable as the network has adjusted to a vastly different competitive route structure. As was discussed in Chapter 3, many airlines have come and gone and the air transportation network has been greatly affected. A longer, more stable time period in domestic air transportation is needed to do a meaningful analysis on connectivity change brought on by deregulation.

Another problem has to do with the choice of rate of change as the main unit of measurement. This created a population bias. As has been stated, larger cities entered the study period with higher connectivity indices and a greater number of professional employees in their workforce simply because of their population size and the agglomerative advantages that exist in larger metropolitan areas. Because those base numbers were already large, their rates of change tended to be comparatively lower than the smaller cities in the study set. A better choice of measurement might have been something like per capita volume flow of air passengers or a per capita accessibility index for connectivity along with a per capita professional employment figure. The usage of

different units of measurement could yield higher significance levels in the general correlation analysis and times series models. Also, using median instead of mean values for the accessibility indices could get rid of some of the problems created by extreme outlier values found in the data set.

The unexpected failure of the time series analysis suggests that a more complex relationship than was tested for in the present study may exist between changes in air service connectivity and professional employment. There are perhaps other factors that influence connectivity and professional employment change that should have been included in the study and the time series model. The model should be expanded to include some important geographic differences between the cities in the study set. These might include population size and hierarchical effects, regional effects, distance from one hub to other hubs, economic health of the city, industrial mix or occupational structure of the city, economic health of the dominant carrier at each city, pre- vs. post-deregulation hub status and connectivity strength. Some of the classification schemes designed in the present study (Tables 4.8 and 5.12) could be incorporated into the model as variables measuring population (hierarchical effects) and connectivity (hub strength). Regional effects appear to be somewhat important, and could be tested explicitly through the usage of dummy variables in a regression model. Future research will directed towards the model specification.

Concluding Remarks and Contributions of the Study

One main contribution of this study is the hub classification scheme designed in Chapter 4. The vast differences in the service levels and connectivity of airports labelled as hubs are something that has not yet been fully addressed in the literature.

Another significant contribution is the realization that the selection of a hub airport by an airline possibly has much more to do with competition at the facility and other airports near the facility than with the employment structure or even economic health of the city in question. Clearly the potential market size of the hub city is important (hence the closing of USAir's Dayton hub), but as the main function of a hub is as a transfer point, it is important to develop hubs along strategic points in the air service network to successfully compete with other hubs for the transfer traffic.

Another significant realization is that nonstop service may not be as important to the business traveler or corporate facility as was assumed. Many non-hubs are so well connected today (albeit indirectly) that travel time and the quantity of flight departures are not a significant problem in spoke cities.

APPENDIX A
CONNECTIVITY INDEX TOTALS

	MATRIX1	MATRIX2	MATRIX3	TOTALS
CAK	8	279	15603	15890
ALB	16	390	24726	25132
ABQ	16	412	22144	22572
ABE	11	367	21136	21514
AMA	4	98	4890	4992
ANC	6	128	8003	8137
ATL*	83	1289	92180	93552
AUS	13	366	19652	20031
BWI*	48	1034	68671	69753
BTR	7	198	10624	10829
BIL	4	99	5381	5484
BHM	13	417	22789	23219
BOI	8	216	11698	11922
BOS	47	1058	68545	69650
BUF	18	513	31244	31775
BTV	6	213	12328	12547
CID	7	222	11758	11987
CHS	11	290	16646	16947
CRW	7	288	14896	15191
CLT*	69	1167	82533	83769
CHA	5	186	9995	10186
ORD*	92	1353	96505	97950
CVG*	63	1171	80949	82183
CLE*	42	953	62754	63749

COS	8	293	14778	15079
CAE	10	306	17362	17678
CMH	22	712	41578	42312
CRP	2	84	4065	4151
DFW*	79	1290	87299	88668
DAY*	30	735	46692	47457
DAB	10	270	16396	16676
DEN*	60	1127	70020	71207
DSM	11	348	19534	19893
DTW*	56	1099	75360	76515
ELP	14	332	18811	19157
EUG	4	99	5830	5933
FMY	20	615	36303	36938
FWA	9	245	14420	14674
FAT	10	240	13188	13438
GRR	10	301	18380	18691
GSO	13	445	24729	25187
GSP	10	308	17973	18291
HRL	3	92	4908	5003
MDT	12	388	22502	22902
BDL	25	704	43004	43733
HNL*	12	389	20488	20889
HOU*	52	1077	68468	69597
HSV	9	335	17355	17699
IND	37	936	58409	59382
ISP	11	318	19307	19636
JAN	9	242	13329	13580
JAX	23	592	34621	35236
MKC	35	929	54985	55949
TYS	11	430	22218	22659
LAS*	37	891	52773	53701
LEX	11	351	19567	19929
LNK	5	190	9746	9941

LIT	8	287	14916	15211
LAX*	48	1112	67518	68678
SDF	17	568	31890	32475
LBB	5	78	4210	4293
MSN	5	179	9636	9820
MLB	9	244	14632	14885
MEM*	47	970	62508	63525
MIA*	34	889	54513	55436
MAF	5	110	5894	6009
MKE	28	809	47773	48610
MSP*	51	1101	69095	70247
MOB	8	244	12818	13070
MLI	5	197	9886	10088
MYR	5	174	9633	9812
BNA*	56	1086	73157	74299
MSY	26	783	45458	46267
NYC*	61	1187	79866	81114
ORF	17	578	32658	33253
OKC	12	389	19952	20353
OMA	15	493	26474	26982
ONT	19	532	28412	28963
MCO*	43	1013	64216	65272
PSP	10	307	16160	16477
PNS	11	298	16966	17275
PHL*	53	1099	73317	74469
PHX*	46	1021	61475	62542
PIT*	65	1181	82278	83524
PWM	7	221	13041	13269
PDX	21	506	27394	27921
PVD	13	433	25282	25728
RDU*	43	791	54158	54992
RNO	14	368	19864	20246
RIC	15	481	27630	28126

ROA	9	312	17009	17330
ROC	16	476	28539	29031
SMF	18	449	24806	25273
MBS	3	115	6016	6134
STL*	64	1203	80577	81844
SLC*	38	793	46861	47692
SAT	17	516	27493	28026
SAN	29	787	43392	44208
SFO*	46	1071	63770	64887
SJC	20	488	27068	27576
SBA	7	191	10484	10682
SRQ	14	447	25751	26212
SAV	7	217	11570	11794
SEA*	33	845	47713	48591
SHV	7	184	10087	10278
FSD	4	168	8187	8359
SBN	9	264	15415	15688
GEG	9	222	11859	12090
SYR	20	555	33711	34286
TLH	8	203	12496	12707
TPA	32	856	52619	53507
TOL	9	275	15804	16088
TUS	11	369	19227	19607
TUL	13	392	20417	20822
DCA*	65	1174	81457	82696
PBI	21	669	38946	39636
ICT	8	274	14094	14376

* indicates hub city

APPENDIX B
CMSA/MSA COUNTY COMPONENTS

ALBANY--Albany, Greene, Montgomery, Rensselaer, Saratoga, Schenectady

ALLENTOWN--Carbon, Lehigh, Northampton, Warren (NJ)

ATLANTA--Barrow, Butts, Cherokee, Clayton, Cobb, Coweta, De Kalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Newton, Paulding, Rockdale, Spalding, Walton

AUSTIN--Hays, Travis, Williamson

BALTIMORE--Anne Arundel, Baltimore, Carroll, Harford, Howard, Queen Anne's, Baltimore city

BIRMINGHAM--Blount, Jefferson, St. Clair, Shelby, Walker

BOSTON--Briston, Essex, Middlesex, Norfolk, Plymouth, Suffolk, Worcester, Hillsborough (NH), Rockingham (NH)

BUFFALO--Erie, Niagara

CHARLOTTE--Cabarrus, Gaston, Lincoln, Mecklenburg, Rowan, Union, York (SC)

CHICAGO--Cook, Du Page, Grundy, Kane, Kendall, Lake, McHenry, Will, Lake (IN), Porter (IN), Kenosha (WI)

CINCINNATI--Butler, Clermont, Hamilton, Warren, Dearborn (IN), Boone (KY), Campbell (KY), Kenton (KY)

CLEVELAND--Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, Summit

COLUMBUS--Delaware, Fairfield, Franklin, Licking, Madison, Pickaway, Union

DALLAS--Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, Tarrant

DAYTON--Clark, Greene, Miami, Montgomery

DENVER--Adams, Arapahoe, Boulder, Denver, Douglas, Jefferson

DETROIT--Lapeer, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, Wayne

GRAND RAPIDS--Kent, Ottawa

GREENSBORO--Davidson, Davie, Forsyth, Guilford, Randolph, Stokes, Yadkin

HARTFORD--Hartford, Litchfield, Middlesex, New London, Tolland

HONOLULU--Honolulu

HOUSTON--Brazoria, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller

INDIANAPOLIS--Boone, Hamilton, Hancock, Hendricks, Johnson, Marion, Morgan, Shelby

JACKSONVILLE--Clay, Duval, Nassau, St. Johns

KANSAS CITY--Cass, Clay, Jackson, Lafayette, Platte, Ray, Johnson (KS), Leavenworth (KS), Miami (KS), Wyandotte (KS)

LAS VEGAS--Clark

LOS ANGELES--Los Angeles, Orange, Riverside, San Bernardino, Ventura

LOUISVILLE--Bullitt, Jefferson, Oldham, Shelby, Clark (IN), Floyd (IN), Harrison (IN)

MEMPHIS--Shelby, Tipton, Crittenden (AR), De Soto (MS)

MIAMI--Broward, Dade

MILWAUKEE--Milwaukee, Ozaukee, Racine, Washington, Waukesha

MINNEAPOLIS--Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Washington, Wright, St. Croix (WI)

NASHVILLE--Cheatham, Davidson, Dickson, Robertson, Rutherford, Sumner, Williamson, Wilson

NEW ORLEANS--Jefferson, Orleans, St. Bernard, St. Charles, St. John the Baptist, St. Tammany (parishes)

NEW YORK/NEWARK--Bronx, Kings, Nassau, New York, Orange, Putnam, Queens, Richmond, Rockland, Suffolk, Westchester, Fairfield (CT), Litchfield (CT), New Haven (CT), Bergen (NJ), Essex (NJ), Hudson (NJ), Hunterdon (NJ), Middlesex (NJ), Monmouth (NJ), Morris (NJ), Ocean (NJ),

Passaic (NJ), Somerset (NJ), Sussex (NJ), Union (NJ)

NORFOLK--Gloucester, James City, York, Chesapeake city, Hampton city, Newport News city, Norfolk city, Poquoson city, Portsmouth city, Suffolk city, Virginia Beach city, Williamsburg city

OKLAHOMA CITY--Canadian, Cleveland, Logan, McClain, Oklahoma, Pottawatomie

ORLANDO--Orange, Osceola, Seminole

PHILADELPHIA--Bucks, Chester, Delaware, Montgomery, Philadelphia, New Castle (DE), Cecil (MD), Burlington (NJ), Camden (NJ), Cumberland (NJ), Gloucester (NJ), Mercer (NJ), Salem (NJ)

PHOENIX--Maricopa

PITTSBURGH--Allegheny, Beaver, Fayette, Washington, Westmoreland

PORTLAND--Clackamas, Multnomah, Washington, Yamhill, Clark (WA)

PROVIDENCE--Bristol, Kent, Newport, Providence, Washington, Bristol (MA), Norfolk (MA), Worcester (MA)

RALEIGH/DURHAM--Durham, Franklin, Orange, Wake

RICHMOND--Charles City, Chesterfield, Dinwiddie, Goochland, Hanover, Henrico, New Kent, Powhatan, Prince George, Colonial Heights city, Hopewell city, Petersburg city, Richmond city

ROCHESTER--Livingston, Monroe, Ontario, Orleans, Wayne

SACRAMENTO--El Dorado, Placer, Sacramento, Yolo

ST. LOUIS--Franklin, Jefferson, St. Charles, St. Louis, St. Louis city, Clinton (IL), Jersey (IL), Madison (IL), Monroe (IL), St. Clair (IL)

SALT LAKE CITY--Davis, Salt Lake, Weber

SAN ANTONIO--Bexar, Comal, Guadalupe

SAN DIEGO--San Diego

SAN FRANCISCO--Alameda, Contra Costa, Marin, Nappa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma

SCRANTON--Columbia, Lackawanna, Luzerne, Monroe, Wyoming

SEATTLE--King, Pierce, Snohomish

SYRACUSE--Madison, Onondaga, Oswego

TAMPA--Hernando, Hillsborough, Pasco, Pinellas

TUCSON--Pima

TULSA--Creek, Osage, Rogers, Tulsa, Wagoner

WASHINGTON, D.C.--Washington, D.C., Calvert (MD), Charles (MD), Frederick (MD), Montgomery (MD), Prince George's (MD), Arlington (VA), Fairfax (VA), Loudoun (VA), Prince William (VA), Stafford (VA), Alexandria city (VA), Fairfax city (VA), Falls Church (VA), Manassas city (VA), Manassas Park city (VA)

WEST PALM BEACH--Palm Beach

APPENDIX C
ADMINISTRATIVE AND AUXILIARY EMPLOYMENT

	1978	1979	1980	1981	1982
NYC	407066	411673	427080	422080	445398
LAX	176709	178964	156601	166875	182647
CHI	184280	181363	182405	187543	170690
SFO	89247	99587	106975	118890	125679
PHL	113066	104949	110831	111562	125857
DTW	164122	157019	149786	137221	126345
BOS	70730	103956	89057	108254	99341
DFW	59990	73337	73672	72094	85305
DCA	36053	26045	35660	38564	43253
HOU	74126	92386	97713	111682	126420
MIA	18905	21664	23691	33017	36799
CLE	54352	74749	65869	70633	77214
ATL	42027	50905	49540	58141	50394
STL	50023	46527	47083	49265	50625
SEA	25448	22619	25273	25025	37881
MSP	61682	66894	67393	74173	82285
SAN	9906	14602	16992	14876	14205
BWI	25614	25898	26146	27088	22332
PIT	52152	52970	54777	63219	58497
PHX	16769	20538	19786	16534	20591
TPA	9913	9821	10442	12006	16657
DEN	28440	29119	30456	31896	35353
CVG	37409	36867	39103	25542	37859
MCI	24726	25577	25164	25485	25597
MKE	22100	21513	22852	23398	23500

PDX	19797	16322	16282	16704	17125
SMF	5242	4468	4747	5627	5339
ORF	7144	7458	8861	6907	7428
CMH	23461	24158	24669	25690	38681
SAT	7006	9644	8977	11251	9833
MSY	18354	17497	19181	21172	24632
IND	20949	18926	18895	17199	18312
BUF	9950	8596	7498	8356	11119
PVD	26897	32039	31878	36184	34087
CLT	14727	18985	20329	20091	20422
BDL	16216	20310	18504	17919	20511
SLC	10157	11107	12014	12028	12658
ROC	20983	11553	12202	13953	22409
MEM	11554	10030	12426	12817	16465
BNA	12215	13683	12170	13637	16299
MCO	5813	6218	6066	7283	7690
SDF	14291	15900	15244	15688	18090
OKC	11739	12356	12802	14365	16572
DAY	15478	19034	18058	16948	17477
GSO	22512	21053	20537	20709	25095
BHM	5331	5435	6257	5561	6403
JAX	934	9922	8723	9643	8898
ALB	12171	13096	14331	13833	14265
RIC	13811	14069	16940	16469	16389
HNL	6850	7622	8178	9203	8691
PBI	989	1698	1966	2109	3186
AUS	1397	2105	2310	1926	2079
AVP	4427	5165	4935	5048	4340
TUL	24862	24017	27011	27321	29902
RDU	7652	6672	7729	8429	8725
ABE	15362	14398	27159	16996	17400
GRR	5350	3595	7588	7434	8241
SYR	8995	8734	8910	9086	9198

TUS	2013	2093	2291	2646	2297
LAS	1226	1472	1339	1530	1547
1983	1984	1985	1986	1987	1988
410012	438752	419826	393184	409800	462305
174085	190268	183975	204263	154243	193284
198148	194124	179601	207975	177831	183688
123500	118369	138236	112534	113071	120469
128266	123983	143438	132686	118283	136055
145021	145580	119960	123625	123612	136782
111235	123128	136076	326434	127195	139258
85915	73184	104327	112270	123612	109966
41458	44066	49516	54173	57874	64363
123159	123038	120691	115653	89684	95362
37063	43220	40413	34557	29737	36602
74263	70794	67672	60087	61799	63586
67460	70945	77279	80038	71902	81958
51886	50728	50399	52374	49668	58350
27753	46557	41800	46835	34835	43944
79018	83770	84420	86184	81342	83141
13535	13617	16555	16822	14452	20394
19915	20000	26452	26815	18978	23615
49268	60870	59391	35936	41670	39973
19675	19331	20699	20636	18189	26590
14876	19652	19028	19603	18633	17663
34267	36437	36860	37079	30229	28880
36552	37670	37819	39849	36373	40221
28157	24311	24183	25868	28287	28219
25530	29026	31917	33736	27150	26324
16454	14937	17963	16283	17220	21206
5695	6882	5175	6726	7439	9434
7178	8058	9291	9835	7481	7560
33834	38819	34468	38264	30347	33304
12071	12327	13793	15104	11949	12736

24143	20088	18974	20936	18587	20067
20305	19800	18981	22483	17911	18733
8558	8829	10248	10982	7964	9583
35112	36136	48512	49808	4562	55189
20376	23880	23003	24674	24745	28694
20828	22924	23408	22195	22024	20467
11988	11908	14109	13931	12510	13648
15928	13644	16470	14029	20781	25239
15359	15672	17378	17672	17061	17647
12322	14029	15291	16416	15246	15407
10086	12549	19610	17373	16156	19778
18121	18069	17315	17702	17578	17861
15705	12204	12223	13645	10588	10481
14938	15062	45560	18954	18827	20826
26550	35164	35859	42438	20717	31971
7669	11132	11125	12834	11654	12588
9351	9663	9985	10819	8902	13207
13786	12566	9182	14528	24211	8077
18728	22548	23934	21992	19504	24126
8165	8714	8423	7731	7960	8826
3109	3240	4169	4432	4499	6493
2594	2814	3189	3108	3440	3653
3871	3883	3884	3945	4546	4618
25767	27640	28002	27909	23304	23188
7828	7702	12316	9928	9893	13365
17914	15451	16996	20145	16400	18671
7403	7448	6727	5529	7383	7677
8009	8972	8712	7999	9150	9573
2843	2658	2754	3830	2820	3293
2246	2246	2305	2305	2449	2147

APPENDIX D
TOTAL EMPLOYMENT BY MSA

	1978	1979	1980	1981	1982
NYC	6589264	6722510	6762097	6783849	6790659
LAX	3956614	4356328	4444624	4441368	4427485
CHI	3106745	3294297	3217807	3132185	3003671
SFO	1887908	2047499	2109344	2148739	2150890
PHL	1931118	2001693	1990948	1989824	1966721
DTW	1628020	1736902	1604170	1522276	1436511
BOS	1960570	2100932	2150637	2190030	2196861
DFW	1153045	1240066	1292432	1337542	1373159
DCA	945750	1054015	1085407	1122460	1110240
HOU	1170627	1276306	1335236	1428129	1509961
MIA	854307	925996	965805	1009033	978951
CLE	1025546	1148918	1108309	1072664	1028846
ATL	771846	824298	842134	869085	878247
STL	872035	912192	899752	886694	873094
SEA	675791	756079	785910	788479	767922
MSP	892320	960289	974425	969049	950443
SAN	456649	506607	533027	538017	552699
BWI	660488	691489	702413	702572	697025
PIT	834680	880587	857639	848641	818590
PHX	450400	516567	532709	543605	547499
TPA	416217	454360	473540	496778	519245
DEN	607885	661734	681166	702802	732425
CVG	512753	613799	605422	592761	577492
MCI	552405	578567	574620	567149	553531
MKE	650217	677024	692466	645318	627339

PDX	446085	486365	495895	485171	457312
SMF	242592	270577	278997	274995	278668
ORF	294766	304139	308058	313181	315668
CMH	392378	448235	448720	440159	429478
SAT	295450	307537	312329	332149	353287
MSY	404171	444950	441135	455014	454334
IND	427131	453702	443212	427776	417578
BUF	412805	429035	421905	408797	391392
PVD	918285	963926	963556	963783	959445
CLT	402120	424717	432470	434026	427325
BDL	542641	578878	595520	601861	592220
SLC	284647	298938	304604	302173	298737
ROC	344235	356396	353371	355403	359566
MEM	299038	311899	308988	304527	307781
BNA	308533	327928	335920	326784	320663
MCO	211048	234223	250287	263057	273502
SDF	334153	355425	346699	342644	327668
OKC	271703	296429	310452	330495	347526
DAY	331363	331266	326236	317269	300073
GSO	339475	359534	359332	363343	362602
BHM	294093	314685	309394	301496	295285
JAX	226746	240207	239554	244292	252405
ALB	231790	245962	247481	247828	246318
RIC	268360	284449	286375	283935	286838
HNL	229033	244952	252617	255656	247754
PBI	151626	172551	186358	201996	206263
AUS	142747	160257	169355	181284	195416
AVP	219313	225567	222482	218139	216577
TUL	237200	249295	263974	276214	287162
RDU	181491	202795	204046	210218	220379
ABE	230384	237920	238055	229775	228423
GRR	222660	241877	238609	235465	228371
SYR	211403	222404	217974	204957	211483

TUS	125193	143973	149545	156241	159234
LAS	157138	186053	196620	195011	193729
1983	1984	1985	1986	1987	1988
6815433	7156862	7409762	7678372	7797530	7882767
4318343	4696663	4901049	5118092	5311411	5479860
2928981	3069308	3146315	3219927	3251211	3380339
2138089	2336252	2438952	2481297	2534682	2621281
1981639	2078043	2166079	2233870	2317414	2375108
1405134	1542405	1630732	1725069	1760620	1764577
2296299	2395737	2516006	2574481	2623145	2677890
1406102	1546900	1652650	1694038	1666154	1670699
1154179	1264847	1371145	1478163	1572264	1647312
1374819	1395559	1391437	1384926	1325571	1346228
967177	1037499	1059883	1110397	1127963	1153702
989526	1034343	1056224	1082964	1088266	1108405
899900	1004172	1106604	1190816	1233837	1271674
863525	915384	954702	986435	982533	1001090
747144	798017	831951	874958	934612	979780
935472	1009026	1062196	1093769	1131243	1161171
548265	605535	655927	703813	734813	767646
697253	756016	803542	842755	900361	903266
747312	782185	789181	797865	813049	823432
560401	643342	716445	755771	778148	802077
529146	586464	636163	652305	684166	717829
718671	768419	801120	806446	639132	767734
570017	599952	623656	658268	688189	720738

539555	578139	611904	628962	643688	649975
596725	632017	644441	653775	672782	695059
444553	474570	495637	508399	526786	555551
278563	30943	334599	355369	386845	410931
326420	357067	384426	402840	420298	433459
430137	459213	483842	514973	539333	558867
352966	370165	395023	399087	398159	392250
427673	441956	437812	440179	422721	418412
411429	444995	464438	488799	511802	537072
373584	386528	404933	416053	418690	432552
987667	1015888	1063227	1101661	1135481	1165177
422810	458046	476600	496535	531224	553984
590400	624002	651498	667169	705341	711714
294032	344613	338280	344267	349265	354419
358419	372936	399554	409307	397542	415692
307097	328268	346979	354541	356225	388017
319980	355820	379899	409957	422636	440110
294373	336816	366373	388669	413135	441127
319111	337560	348638	354550	367667	374907
328789	335128	334407	324650	308785	388017
295569	314543	333606	341134	354334	363362
356850	383842	404258	418037	426809	447921
280779	302708	318477	335682	338238	343970
258825	278288	311577	314394	328335	343162
248603	264244	271937	285152	299344	298092
285962	304643	321865	338885	353996	369715
247118	256901	262794	274517	284594	297324
211477	241476	260143	279703	294969	311676
208412	242293	269135	275244	262785	254614
212522	224016	230534	237499	244980	256691
267219	271931	279052	277215	261849	264621
226723	256288	276763	292655	300628	324280
218363	233121	239810	239652	247421	252978

227683	251607	269420	282216	301761	309410
210870	226612	236931	245382	244699	259554
157231	175446	187297	192734	204451	209786
187086	204475	215756	225403	253582	270247

APPENDIX E
TOTAL ENPLANEMENTS BY MSA

	1978	1979	1980	1981	1982
NYC	21289208	22704666	21726444	21218167	23077670
LAX	13479147	18543055	16341818	15768931	16058981
CHI	21575602	211178522	19417854	16906634	16699134
SFO	8598388	12111016	10330368	9624812	10385733
PHL	4138542	4528807	4058167	3581634	3844822
DTW	4842441	5524630	5050735	4749836	4790521
BOS	6286825	7093394	6844951	6622905	7111936
DFW	9638242	11419465	12775213	13923029	14685061
DCA	8036073	8585305	7756053	7282727	7132925
HOU	4632700	5617114	6806627	7515759	8472275
MIA	8993922	10476248	11037003	10018502	9833572
CLE	3541267	3693940	2989234	2619705	2521662
ATL	18226652	20797535	19994113	18702918	17322680
STL	4714822	5582691	5319480	5126290	5735255
SEA	4112657	4736290	4352439	4281971	4613282
MSP	3952367	4697295	4384643	4523898	5221988
SAN	2051226	3301759	2536337	2525428	2739957
BWI	1690098	1759614	1652494	1521330	1903299
PIT	4635645	5280953	5381659	4183339	4607761
PHX	3056169	3587529	3380121	3397867	3950386
TPA	3106218	3693478	3600730	3184121	3560548
DEN	8861423	9654132	9615785	10437142	11404157
CVG	1536142	1601087	1391638	1331791	1598641
MCI	2789820	3133092	2620100	2272343	2556815
MKE	1460755	1711072	1623318	1550847	1562381

PDX	2058535	2154581	1804395	1731302	1850515
SMF	667303	1418324	1095186	1080347	1169559
ORF	887487	937337	951175	1099872	1186556
CMH	1290199	1383721	1219950	1121737	1234349
SAT	1111959	1336768	1533658	1626755	1667239
MSY	3018722	3137699	3107183	2928436	2852632
IND	1556591	1709074	1464569	1257385	1260612
BUF	1739843	1742871	1540313	1333165	1613151
PVD	500144	494879	459316	319354	305433
CLT	1456132	1559557	1480787	1894928	2768882
BDL	1476451	1604360	1401135	1162993	1144221
SLC	2022249	2173282	1996706	1902459	2680184
ROC	901125	946427	870480	736282	843811
MEM	2344531	2576902	2148730	1945933	2189650
BNA	1156836	1223219	1122084	1033206	1079076
MCO	2446984	3098437	3124568	2866389	3268933
SDF	1051933	1127869	993355	848184	874842
OKC	1042187	1125830	1076613	1118403	1261935
DAY	979209	999278	889035	707426	774638
GSO	668639	739975	731386	756800	707064
BHM	773652	797616	705297	643513	592253
JAX	820113	896136	872979	858902	982157
ALB	663818	718869	659135	414205	454903
RIC	567816	675934	619775	565832	461362
HNL	5864914	5874876	5654546	5442620	5664918
PBI	894810	1171058	1282940	1263192	1570159
AUS	517030	641368	887905	973399	1106150
AVP	167096	180210	151498	96811	81323
TUL	952622	1033231	1029951	1112368	1258053
RDU	792640	910504	866007	828176	911866
ABE	280296	309907	273839	152033	136490
GRR	421734	468289	429505	332870	370959
SYR	831029	892659	794244	717589	866290

TUS	837498	975735	875881	821265	877377
LAS	3957489	4739343	4629185	4232324	4314916
1983	1984	1985	1986	1987	1988
26880949	31752282	33938478	33958749	32755259	32820184
17368961	17713817	19532270	21648396	23219241	22836344
18933514	20026450	22748376	26492993	28663219	29770857
11650159	12239767	12955615	14186514	15034788	15173602
3980574	4365216	4760972	5423885	6602687	6633677
4888149	5357166	7163840	8206266	9254473	9343770
8044651	8702896	9112901	9695876	10255305	10141298
15682626	18482238	20935812	21822524	22340190	23488986
7885801	8191080	9015583	10890580	12030011	11586627
8504411	9198607	10017397	10281584	10858793	10712269
9942910	9949648	10669134	12166233	13271508	13360799
2626602	2751460	3023714	3092753	3102547	3547258
18648189	18920261	20678095	21376831	22649433	21824125
7815390	7946046	9555195	9825338	9727239	9554454
4954028	5060828	5709488	6651868	6825552	6825513
5781536	6127495	7250302	7981852	8310150	8170952
3142844	3505205	3930854	4558449	4901362	5180587
2296538	2876946	3408608	3847977	4009780	4369596
5544359	6259853	7002343	7469663	8156015	8378639
4800711	5750659	6713293	7719503	8784880	9455324
3830148	3962211	4240557	4675116	4798969	4538643
11404005	12812656	13862996	16087330	15593583	14441817
1769830	1703819	2014386	2136184	3264622	3542865
2399224	3100434	3424127	3911406	4481372	4469974
1352044	1115865	1350401	1514107	1619426	1779140

2074741	2150617	2526852	2414960	2834327	2823311
1232658	1222395	1349631	1606346	1749987	1792347
1395088	1505242	1554449	1540653	1550095	1491928
1426267	1528154	1525507	1572763	1695005	1758894
1823971	2053088	2162423	2243454	2425259	2392332
2868966	3193181	2912675	3040026	3311172	3199970
1300098	1442102	1746752	2029928	2273057	2405638
1706336	1803770	1681206	1731363	1728690	1780070
314620	398756	553540	715688	864078	944843
3763812	4226187	5102703	5687255	6021104	6619780
1420664	1535368	1705896	1998477	2267686	2321986
3237442	3477711	4137044	4650983	4728595	4729937
861319	895372	1229991	1241968	1254005	1241528
2359442	2283425	3469318	4177169	5023047	4532572
1108572	1216188	1395487	2165808	2987233	3244014
3721059	4108413	4848771	5946686	7074737	7473086
855970	845914	912181	946140	1034162	1013770
1248378	1446365	1464565	1477962	1506126	1492526
1191509	1430970	1732155	2140242	2166547	2140470
740899	785241	1102525	1039838	1026113	993682
612126	603114	714884	754100	912204	983167
1044359	1056365	1160053	1373191	1407222	1287939
476936	498531	617558	733879	767609	817167
476137	564687	703497	807801	873569	850593
5375172	5978421	5979712	7352027	7773253	8396313
1776550	1823150	1795222	1985478	2229254	2360993
1248759	1643714	1828768	1830831	1928535	1922447
88746	97179	104022	114461	143513	150856
1264143	1393037	1397434	1382816	1388360	1362402
1122732	1289108	1345077	1441832	2316211	3517525
144298	164576	167965	221559	263930	295168
492820	510322	569248	577526	608976	596869
1024852	1173429	1318086	1381238	1499559	1473759

980374	1012189	1191205	1378830	1525859	1362402
4588640	4322838	4627078	5329158	6836053	6864803

APPENDIX F
TOTAL NONSTOP DESTINATIONS REACHED FROM EACH MSA

	1978	1979	1980	1981	1982
NYC	51	51	52	52	52
LAX	40	39	39	38	38
CHI	57	57	57	57	56
SFO	31	30	30	29	27
PHL	42	42	42	42	40
DTW	37	40	35	33	33
BOS	31	35	36	38	37
DFW	41	46	46	48	48
DCA	50	49	46	45	46
HOU	30	33	36	37	40
MIA	30	29	29	28	28
CLE	39	39	34	33	30
ATL	46	50	52	52	54
STL	37	40	41	41	43
SEA	17	18	19	20	20
MSP	24	27	27	27	29
SAN	25	23	19	17	17
BWI	28	26	26	26	29
PIT	37	41	44	46	46
PHX	19	19	20	20	21
TPA	32	32	32	32	30
DEN	33	38	38	41	41
CVG	26	25	25	25	28
MCI	28	26	25	25	27

MKE	24	24	24	26	25
PDX	14	12	12	12	13
SMF	8	8	9	10	10
ORF	13	12	11	11	13
CMH	19	19	20	20	21
SAT	10	7	8	8	10
MSY	25	21	23	23	24
IND	24	22	22	22	22
BUF	23	20	19	16	16
PVD	8	8	8	8	9
CLT	22	24	24	24	27
BDL	18	18	21	21	21
SLC	14	14	14	15	18
ROC	12	12	12	12	13
MEM	24	24	28	29	29
BNA	19	19	19	21	21
MCO	18	22	23	24	26
SDF	18	20	20	23	21
OKC	15	13	11	10	12
DAY	17	15	16	16	17
GSO	14	15	15	17	16
BHM	14	12	12	12	10
JAX	12	12	13	13	14
ALB	11	11	11	11	11
RIC	12	12	13	14	12
HNL	5	5	6	7	6
PBI	11	11	11	12	14
AUS	4	3	3	3	5
AVP	6	5	5	5	6
TUL	11	11	11	12	12
RDU	13	13	12	12	14
ABE	7	7	8	8	8
GRR	5	5	5	5	6

SYR	13	12	11	11	13
TUS	7	8	9	10	10
LAS	23	24	24	25	23
1983	1984	1985	1986	1987	1988
51	49	49	49	48	48
37	37	37	37	37	37
56	56	56	56	56	56
26	25	26	27	27	28
40	40	40	40	43	43
33	36	38	40	43	43
37	37	37	39	40	40
48	48	48	48	49	50
46	46	47	48	49	49
40	31	35	37	38	38
28	28	28	28	27	27
31	31	33	33	34	37
54	54	54	54	54	56
43	43	43	43	46	46
19	18	20	20	22	22
30	31	36	38	40	40
17	17	19	19	20	21
31	34	36	37	37	38
46	44	46	48	48	49
23	25	27	30	31	31
30	29	30	30	30	32
41	41	40	40	40	40
28	30	32	34	40	43
27	33	33	33	31	31
22	19	22	25	25	25
14	13	13	13	13	13
10	10	10	11	11	11
14	14	14	15	15	16

22	22	22	22	22	22
10	11	11	13	13	13
24	25	24	23	23	23
22	24	24	26	26	26
16	16	16	16	16	16
9	9	9	9	10	10
28	29	31	31	37	40
22	22	22	22	22	22
20	21	24	25	25	25
13	13	15	15	15	16
27	27	34	36	38	38
21	20	22	26	30	34
31	33	35	38	39	38
21	20	19	18	17	17
12	13	12	12	12	11
22	23	23	25	25	25
15	15	15	15	15	15
10	9	10	12	12	12
14	14	14	16	16	17
12	13	13	13	13	13
13	12	13	13	13	13
6	5	7	9	10	11
15	15	15	18	18	19
7	8	7	7	7	7
6	7	6	6	5	5
12	11	11	12	12	12
15	16	17	17	27	29
8	8	8	8	8	8
7	7	7	7	8	9
13	15	15	15	18	18
8	8	8	9	9	10
21	19	23	25	27	28

APPENDIX G
ACCESSIBILITY INDICES: 1978-1988

1978	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	10	345	9031	9386
ABE	7	303	7657	7967
ATL	46	1177	34197	35420
AUS	4	121	3275	3400
BWI	29	844	23553	24426
BHM	14	429	11855	12298
BOS	31	873	24710	25614
BUF	23	650	18141	18814
CLT	22	616	17401	18039
CHI	57	1276	37839	39172
CVG	26	834	23389	24249
CLE	39	1081	30978	32098
CMH	19	660	18060	18739
DFW	41	1052	30381	31474
DAY	17	590	16343	16950
DEN	33	927	26260	27220
DTW	37	1037	29700	30774
GSO	14	441	11757	12212
BDL	18	599	16246	16863
HNL	5	186	4896	5087
HOU	30	844	23484	24358
IND	24	783	21790	22597
JAX	12	413	10983	11408
GRR	5	181	4957	5143
MKC	28	852	23739	24619

LAS	23	705	19497	20225
LAX	40	1061	30342	31443
SDF	18	574	15882	16474
MEM	24	750	20936	21710
MIA	30	926	25879	26835
MKE	24	797	21944	22765
MSP	24	766	21271	22061
BNA	19	626	17143	17788
MSY	25	745	20810	21580
NYC	51	1221	35966	37238
ORF	13	452	11832	12297
OKC	15	479	13031	13525
MCO	18	591	16235	16844
PHL	42	1094	31716	32852
PHX	19	590	15946	16555
PIT	37	943	27522	28502
PDX	14	423	11699	12136
PVD	8	343	8670	9021
RDU	13	424	11431	11868
RIC	12	391	10310	10713
ROC	12	421	11287	11720
SMF	8	258	6903	7169
STL	39	1088	31185	32312
SLC	14	437	12081	12532
SAT	10	318	8561	8889
SAN	25	741	20419	21185
SFO	31	891	24816	25738
AVP	6	226	5884	6116
SEA	17	532	14400	14949
SYR	13	467	12372	12852
TPA	32	935	26455	27422
TUS	7	236	6321	6564
TUL	11	369	9978	10358

DCA	50	1242	36261	37553
PBI	11	401	10543	10955

1979	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	11	393	10407	10811
ABE	7	302	7784	8093
ATL	50	1233	36896	38179
AUS	3	89	2414	2506
BWI	26	787	22069	22882
BHM	12	384	10698	11094
BOS	34	968	27889	28891
BUF	20	602	16910	17532
CLT	24	701	19981	20706
CHI	57	1284	38854	40195
CVG	25	838	23625	24488
CLE	38	1078	31392	32508
CMH	19	667	18443	19129
DFW	46	1152	34095	35293
DAY	15	518	14604	15137
DEN	38	1048	30390	31476
DTW	37	1056	30657	31750
GSO	15	496	13344	13855
BDL	18	609	16763	17390
HNL	5	187	5006	5198
HOU	36	992	28581	29609
IND	22	732	20655	21409
JAX	12	424	11388	11824
GRR	5	183	5104	5292
MKC	26	841	23580	24447
LAS	24	763	21279	22066
LAX	39	1075	31224	32338
SDF	20	650	18150	18820
MEM	26	813	23172	24011

MIA	29	916	25907	26852
MKE	24	819	22805	23648
MSP	27	867	24450	25344
BNA	19	639	17728	18386
MSY	21	710	19859	20590
NYC	51	1236	37050	38337
ORF	12	436	11527	11975
OKC	13	464	12583	13060
MCO	22	727	20223	20972
PHL	42	1116	32876	34034
PHX	19	615	16807	17441
PIT	41	1081	31777	32899
PDX	12	376	10396	10784
PVD	8	349	8929	9286
RDU	13	427	11679	12119
RIC	12	392	10510	10914
ROC	12	429	11660	12101
SMF	8	263	7094	7365
STL	40	1107	32402	33549
SLC	14	449	12520	12983
SAT	7	270	6905	7182
SAN	23	714	19800	20537
SFO	30	885	24991	25906
AVP	5	189	4959	5153
SEA	18	560	15327	15905
SYR	12	447	11880	12339
TPA	32	950	27307	28289
TUS	8	288	7765	8061
TUL	11	392	10630	11033
DCA	48	1224	36143	37415
PBI	11	413	10963	11387

1980	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	11	397	10485	10893
ABE	8	354	9090	9452
ATL	52	1263	38218	39533
AUS	3	90	2477	2570
BWI	26	791	22359	23176
BHM	12	386	10872	11270
BOS	36	1003	29299	30338
BUF	19	581	16351	16951
CLT	24	707	20287	21018
CHI	57	1293	39312	40662
CVG	25	846	23958	24829
CLE	34	1033	29866	30933
CMH	20	687	19224	19931
DFW	46	1162	34549	35757
DAY	16	543	15469	16028
DEN	38	1052	30652	31742
DTW	35	1037	30081	31153
GSO	15	501	13513	14029
BDL	21	701	19467	20189
HNL	6	202	5510	5718
HOU	36	998	28919	29953
IND	22	738	20923	21683
JAX	13	462	12492	12967
GRR	5	177	5054	5236
MKC	25	804	22604	23433
LAS	24	762	21279	22065
LAX	39	1080	31481	32600
SDF	20	650	18324	18994
MEM	28	868	24952	25848
MIA	29	921	26209	27159
MKE	24	820	22928	23772
MSP	27	871	24648	25546

BNA	19	641	17974	18634
MSY	23	796	22240	23059
NYC	52	1252	37821	39125
ORF	12	438	11627	12077
OKC	11	399	10761	11171
MCO	23	764	21415	22202
PHL	42	1120	33178	34340
PHX	20	629	17207	17856
PIT	44	1136	33794	34974
PDX	12	375	10408	10795
PVD	8	355	9056	9419
RDU	12	394	10764	11170
RIC	13	437	11677	12127
ROC	12	434	11846	12292
SMF	9	280	7676	7965
STL	41	1138	33486	34665
SLC	14	449	12514	12977
SAT	8	317	8132	8457
SAN	19	611	16920	17550
SFO	30	884	25067	25981
AVP	5	192	5060	5257
SEA	19	590	16257	16866
SYR	11	414	10977	11402
TPA	32	960	27763	28755
TUS	9	337	8961	9307
TUL	11	398	10742	11151
DCA	46	1198	35437	36681
PBI	11	416	11102	11529

1981	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	11	396	10517	10924
ABE	8	352	9120	9480
ATL	52	1275	38965	40292

AUS	3	92	2562	2657
BWI	26	792	22582	23400
BHM	12	394	11282	11688
BOS	38	1040	30806	31884
BUF	16	514	14237	14767
CLT	24	714	20700	21438
CHI	56	1295	39695	41046
CVG	26	894	25507	26427
CLE	33	1023	29788	30844
CMH	20	692	19560	20272
DFW	47	1203	36088	37338
DAY	16	548	15743	16307
DEN	41	1114	32904	34059
DTW	33	1005	29285	30323
GSO	17	569	15729	16315
BDL	21	702	19645	20368
HNL	6	201	5540	5747
HOU	37	1035	30427	31499
IND	22	751	21529	22302
JAX	13	463	12670	13146
GRR	5	176	5088	5269
MKC	25	815	23149	23989
LAS	24	769	21641	22434
LAX	38	1082	31702	32822
SDF	23	769	21873	22665
MEM	29	921	26611	27561
MIA	28	913	26167	27108
MKE	26	866	24592	25484
MSP	28	899	25805	26732
BNA	21	702	20069	20792
MSY	23	806	22804	23633
NYC	52	1265	38565	39882
ORF	12	438	11708	12158

OKC	10	381	10231	10622
MCO	24	814	22983	23821
PHL	42	1128	33741	34911
PHX	20	638	17562	18220
PIT	46	1193	35953	37192
PDX	12	380	10632	11024
PVD	8	357	9155	9520
RDU	12	394	10860	11266
RIC	12	422	11270	11704
ROC	12	436	11980	12428
SMF	10	295	8264	8569
STL	42	1157	34416	35615
SLC	15	503	13941	14459
SAT	8	324	8364	8696
SAN	17	543	15181	15741
SFO	29	883	25133	26045
AVP	5	193	5105	5303
SEA	20	623	17411	18054
SYR	11	412	10998	11421
TPA	32	970	28346	29348
TUS	10	352	9561	9923
TUL	12	426	11729	12167
DCA	45	1167	35051	36263
PBI	12	453	12247	12712

1982	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	11	402	10712	11125
ABE	8	356	9289	9653
ATL	54	1315	40512	41881
AUS	5	190	5110	5305

BWI	29	836	24385	25250
BHM	10	347	9869	10226
BOS	37	1034	30717	31788
BUF	16	522	14547	15085
CLT	27	824	24007	24858
CHI	56	1325	40852	42233
CVG	28	936	27242	28206
CLE	30	973	28365	29368
CMH	21	725	20778	21524
DFW	47	1222	36992	38261
DAY	17	586	16975	17578
DEN	41	1132	33717	34890
DTW	33	1012	29751	30796
GSO	16	566	15703	16285
BDL	21	716	20191	20928
HNL	6	199	5562	5767
HOU	38	1072	31929	33039
IND	22	754	21890	22666
JAX	14	501	13940	14455
GRR	6	200	6013	6219
MKC	29	916	26705	27650
LAS	23	763	21614	22400
LAX	38	1099	32461	33598
SDF	21	722	20700	21443
MEM	29	929	27070	28028
MIA	28	933	26938	27899
MKE	24	827	23567	24418
MSP	29	940	27259	28228
BNA	21	708	20446	21175
MSY	24	822	23531	24377
NYC	52	1287	39437	40776
ORF	13	486	13155	13654
OKC	12	429	11860	12301

MCO	27	898	26071	26996
PHL	40	1101	33023	34164
PHX	21	651	18210	18882
PIT	46	1212	36747	38005
PDX	13	438	12163	12614
PVD	9	374	9741	10124
RDU	14	430	12257	12701
RIC	12	430	11617	12059
ROC	13	428	11869	12310
SMF	10	298	8440	8748
STL	43	1187	35687	36917
SLC	18	567	15968	16553
SAT	10	369	9873	10252
SAN	17	553	15579	16149
SFO	27	821	23594	24442
AVP	6	205	5585	5796
SEA	20	632	17824	18476
SYR	13	451	12352	12816
TPA	30	930	27276	28236
TUS	10	355	9729	10094
TUL	12	437	12098	12547
DCA	46	1201	36411	37658
PBI	14	510	14073	14597

1983	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	12	425	11627	12064
ABE	8	357	9445	9810
ATL	54	1332	41190	42576
AUS	7	270	7180	7457
BWI	31	901	26693	27625
BHM	10	347	9923	10280
BOS	37	1050	31345	32432
BUF	16	528	14871	15415

CLT	28	861	25432	26321
CHI	56	1343	41551	42950
CVG	28	945	27709	28682
CLE	31	1002	29470	30503
CMH	22	762	22042	22826
DFW	48	1250	38064	39362
DAY	22	753	21787	22562
DEN	41	1137	33969	35147
DTW	33	1023	30266	31322
GSO	15	553	15346	15914
BDL	22	740	21179	21941
HNL	6	196	5509	5711
HOU	38	1075	32097	33210
IND	22	762	22273	23057
JAX	14	510	14316	14840
GRR	7	222	6805	7034
MKC	29	919	26828	27776
LAS	21	697	19692	20410
LAX	37	1079	31906	33022
SDF	21	728	21038	21787
MEM	27	849	25089	25965
MIA	28	946	27512	28486
MKE	22	770	22066	22858
MSP	30	969	28237	29236
BNA	21	717	20854	21592
MSY	24	825	23758	24607
NYC	51	1293	39677	41021
ORF	14	518	14372	14904
OKC	12	432	11915	12359
MCO	31	981	28920	29932
PHL	40	1115	33600	34755
PHX	23	667	18887	19577
PIT	46	1223	37249	38518

PDX	14	462	12887	13363
PVD	9	376	9933	10318
RDU	15	461	13449	13925
RIC	12	433	11865	12310
ROC	13	432	12106	12551
SMF	10	301	8474	8785
STL	43	1198	36110	37351
SLC	20	586	16735	17341
SAT	10	376	10081	10467
SAN	17	552	15516	16085
SFO	26	788	22604	23418
AVP	6	204	5635	5845
SEA	19	610	17067	17696
SYR	13	455	12599	13067
TPA	30	943	27861	28834
TUS	8	280	7689	7977
TUL	12	438	12142	12592
DCA	46	1215	36962	38223
PBI	15	543	15224	15782

1984	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	13	462	12853	13328
ABE	8	359	9565	9932
ATL	54	1338	41525	42917
AUS	8	293	7999	8300
BWI	34	986	29586	30606
BHM	9	310	8867	9186
BOS	37	1054	31669	32760
BUF	16	535	15170	15721
CLT	29	891	26543	27463
CHI	56	1349	41908	43313
CVG	30	994	29406	30430
CLE	31	1004	29713	30748

CMH	22	770	22355	23147
DFW	48	1251	38229	39528
DAY	23	778	22793	23594
DEN	41	1138	34140	35319
DTW	36	1082	32469	33587
GSO	15	557	15578	16150
BDL	22	744	21460	22226
HNL	5	177	4912	5094
HOU	31	948	27914	28893
IND	24	829	24371	25224
JAX	14	506	14366	14886
GRR	7	226	6896	7129
MKC	33	1013	29976	31022
LAS	19	654	18357	19030
LAX	37	1081	32113	33231
SDF	20	699	20250	20969
MEM	27	857	25341	26225
MIA	28	952	27818	28798
MKE	19	692	19765	20476
MSP	31	997	29335	30363
BNA	20	684	19976	20680
MSY	25	850	24702	25577
NYC	49	1275	39242	40566
ORF	14	521	14554	15089
OKC	13	461	12888	13362
MCO	33	1038	30960	32031
PHL	40	1124	34078	35242
PHX	25	718	20676	21419
PIT	44	1193	36426	37663
PDX	13	426	11879	12318
PVD	9	376	10032	10417
RDU	16	495	14631	15142
RIC	12	434	12001	12447

ROC	13	438	12382	12833
SMF	10	301	8470	8781
STL	43	1199	36298	37540
SLC	21	618	17814	18453
SAT	11	400	10936	11347
SAN	17	545	15428	15990
SFO	25	761	21812	22598
AVP	7	254	6945	7206
SEA	18	583	16328	16929
SYR	15	517	14696	15228
TPA	29	938	27811	28778
TUS	8	276	7648	7932
TUL	11	391	10956	11358
DCA	46	1218	37266	38530
PBI	15	537	15234	15786

1985	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	13	471	13514	13998
ABE	8	366	10065	10439
ATL	54	1389	44304	45747
AUS	7	294	8188	8489
BWI	36	1072	33082	34190
BHM	10	355	10564	10929
BOS	37	1095	33785	34917
BUF	16	549	16028	16593
CLT	31	961	29683	30675
CHI	56	1401	44757	46214
CVG	32	1064	32497	33593
CLE	33	1090	33357	34480
CMH	22	803	23933	24758
DFW	48	1300	40904	42252
DAY	23	801	24176	25000
DEN	40	1168	35983	37191

DTW	38	1161	35936	37135
GSO	15	571	16447	17033
BDL	22	767	22758	23547
HNL	7	270	7747	8024
HOU	35	1097	33376	34508
IND	24	859	25952	26835
JAX	14	518	15170	15702
GRR	7	240	7453	7700
MKC	33	1060	32267	33360
LAS	23	785	23262	24070
LAX	37	1132	34632	35801
SDF	19	683	20381	21083
MEM	34	1040	32146	33220
MIA	28	985	29616	30629
MKE	22	792	23542	24356
MSP	36	1144	35058	36238
BNA	22	774	23307	24103
MSY	24	855	25469	26348
NYC	49	1324	41854	43227
ORF	14	534	15377	15925
OKC	12	452	12909	13373
MCO	35	1122	34528	35685
PHL	40	1163	36225	37428
PHX	27	793	23910	24730
PIT	46	1274	40117	41437
PDX	13	440	12754	13207
PVD	9	382	10540	10931
RDU	17	541	16498	17056
RIC	13	474	13670	14157
ROC	15	509	14802	15326
SMF	10	310	9103	9423
STL	43	1248	38887	40178
SLC	24	728	22017	22769

SAT	11	411	11653	12075
SAN	19	643	18968	19630
SFO	26	832	24739	25597
AVP	6	244	6797	7047
SEA	20	666	19501	20187
SYR	15	529	15493	16037
TPA	30	986	30113	31129
TUS	8	286	8262	8556
TUL	11	404	11722	12137
DCA	47	1281	40298	41626
PBI	15	555	16203	16773

1986	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	13	477	13984	14474
ABE	8	372	10448	10828
ATL	54	1431	46581	48066
AUS	7	301	8622	8930
BWI	37	1114	35260	36411
BHM	12	442	13526	13980
BOS	39	1175	37099	38313
BUF	16	555	16560	17131
CLT	31	987	31189	32207
CHI	56	1444	47057	48557
CVG	34	1141	35714	36889
CLE	33	1118	34976	36127
CMH	22	827	25181	26030
DFW	48	1347	43233	44628
DAY	25	886	27426	28337
DEN	40	1207	37912	39159
DTW	40	1235	39139	40414
GSO	15	580	17076	17671
BDL	22	783	23684	24489
HNL	9	327	9842	10178

HOU	37	1156	36062	37255
IND	26	957	29419	30402
JAX	16	587	17665	18268
GRR	7	251	7914	8172
MKC	33	1091	33885	35009
LAS	25	825	25143	25993
LAX	37	1173	36586	37796
SDF	18	680	20625	21323
MEM	36	1113	35209	36358
MIA	28	1012	31092	32132
MKE	25	894	27350	28269
MSP	38	1196	37498	38732
BNA	26	918	28439	29383
MSY	23	855	25938	26816
NYC	49	1361	43915	45325
ORF	15	582	17189	17786
OKC	12	462	13543	14017
MCO	36	1166	36713	37915
PHL	40	1193	37978	39211
PHX	30	924	28524	29478
PIT	48	1326	42757	44131
PDX	13	448	13348	13809
PVD	9	388	10937	11334
RDU	17	549	17124	17690
RIC	13	483	14227	14723
ROC	13	489	14301	14803
SMF	11	353	10724	11088
STL	43	1288	40935	42266
SLC	25	758	23507	24290
SAT	13	480	14107	14600
SAN	19	661	19881	20561
SFO	27	884	26947	27858
AVP	6	247	7027	7280

SEA	20	682	20393	21095
SYR	15	534	15991	16540
TPA	30	1015	31645	32690
TUS	9	317	9495	9821
TUL	12	440	13139	13591
DCA	48	1344	43268	44660
PBI	18	676	20370	21064

1987	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB	13	486	14816	15315
ABE	8	379	10978	11365
ATL	54	1484	49782	51320
AUS	7	305	9041	9353
BWI	37	1162	37890	39089
BHM	12	469	14657	15138
BOS	40	1253	40743	42036
BUF	16	586	18051	18653
CLT	40	1289	42312	43641
CHI	56	1499	50337	51892
CVG	40	1293	42286	43619
CLE	34	1176	37961	39171
CMH	22	873	27231	28126
DFW	49	1413	46700	48162
DAY	25	922	29333	30280
DEN	40	1248	40285	41573
DTW	43	1327	43567	44937
GSO	15	611	18558	19184
BDL	22	829	25706	26557
HNL	10	369	11423	11802
HOU	38	1222	39321	40581
IND	26	990	31308	32324
JAX	16	617	19122	19755
GRR	8	311	9828	10147

MKC	30	1075	33909	35014
LAS	27	893	28053	28973
LAX	37	1214	38936	40187
SDF	17	680	21014	21711
MEM	37	1181	38459	39677
MIA	27	1027	32312	33366
MKE	25	932	29307	30264
MSP	39	1266	40899	42204
BNA	30	1076	34314	35420
MSY	23	887	27655	28565
NYC	49	1413	47035	48497
ORF	15	622	18790	19427
OKC	12	470	14181	14663
MCO	36	1213	39341	40590
PHL	43	1297	42827	44167
PHX	31	994	31477	32502
PIT	48	1379	45818	47245
PDX	13	460	14087	14560
PVD	10	446	13099	13555
RDU	27	868	28216	29111
RIC	13	513	15587	16113
ROC	13	511	15422	15946
SMF	11	359	11284	11654
STL	49	1420	47004	48473
SLC	25	777	24764	25566
SAT	13	501	15104	15618
SAN	20	716	22201	22937
SFO	27	921	28815	29763
AVP	5	243	6990	7238
SEA	22	776	24001	24799
SYR	18	659	20387	21064
TPA	30	1065	34115	35210
TUS	9	323	9976	10308

	1988	MATRIX1	MATRIX2	MATRIX3	TOTAL
TUL		12	451	13859	14322
DCA		49	1417	47189	48655
PBI		18	711	22040	22769

	1988	MATRIX1	MATRIX2	MATRIX3	TOTAL
ALB		13	493	15144	15650
ABE		8	384	11235	11627
ATL		56	1523	51807	53386
AUS		7	309	9228	9544
BWI		38	1206	39865	41109
BHM		12	479	15041	15532
BOS		40	1276	41923	43239
BUF		16	598	18542	19156
CLT		42	1338	44575	45955
CHI		57	1535	52155	53747
CVG		43	1360	45159	46562
CLE		37	1249	41085	42371
CMH		22	890	27956	28868
DFW		50	1452	48656	50158
DAY		25	938	30137	31100
DEN		40	1268	41343	42651
DTW		43	1351	44799	46193
GSO		15	624	19068	19707
BDL		22	845	26387	27254
HNL		11	429	13211	13651
HOU		38	1242	40369	41649
IND		26	1005	32076	33107
JAX		17	651	20581	21249
GRR		9	367	11527	11903
MKC		30	1093	34778	35901
LAS		28	936	29877	30841
LAX		37	1234	39979	41250
SDF		17	694	21578	22289

MEM	37	1196	39395	40628
MIA	27	1046	33199	34272
MKE	25	949	30109	31083
MSP	39	1286	41979	43304
BNA	31	1121	36088	37240
MSY	23	903	28391	29317
NYC	49	1438	48400	49887
ORF	16	687	20797	21500
OKC	12	474	14451	14937
MCO	36	1232	40355	41623
PHL	43	1320	44040	45403
PHX	31	1012	32304	33347
PIT	49	1421	47827	49297
PDX	13	466	14406	14885
PVD	12	503	15169	15684
RDU	29	916	30197	31142
RIC	13	526	16085	16624
ROC	13	521	15838	16372
SMF	11	363	11541	11915
STL	49	1445	48345	49839
SLC	25	788	25358	26171
SAT	13	509	15465	15987
SAN	21	737	23163	23921
SFO	28	973	30818	31819
AVP	5	246	7143	7394
SEA	22	790	24659	25471
SYR	18	669	20894	21581
TPA	30	1084	35036	36150
TUS	10	355	11177	11542
TUL	12	456	14149	14617
DCA	49	1441	48509	49999
PBI	19	773	24028	24820

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Edward J. Malecki, Chairman
Professor of Geography

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and qualtiy, as a dissertation for the degree of Doctor of Philosophy.

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